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TERRAIN ANALYSIS PROCEDURAL GUIDE FOR VEGETATION.(U)
MAR 79 J A MESSMORE, T C VOGEL, A R PEARSON

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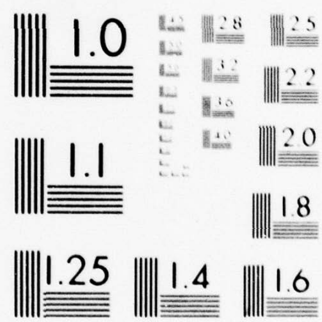

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Terrain analysis procedural guide for vegetation

(Report No. 1 in the ETL series on guides for Army terrain analysts)

Jeffrey A. Messmore

Theodore C. Vogel

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MARCH 1979

U.S. ARMY CORPS OF ENGINEERS

ENGINEER TOPOGRAPHIC LABORATORIES

FORT BELVOIR, VIRGINIA 22060

ETL

ERRATA SHEET

ETL REPORT NO. ETL-0178

Terrain Analysis Procedural Guide for Vegetation

Page 2, Section II.C., Aerial Imagery; change page number from 13 to 15.

Page 3, Appendix C-2; change Map Sources to read Vegetation Maps.

Page 7, Table B1, Regression and Rule-of-Thumb Equations; add 117 to page column.

Page 10, Modify the right hand column of the location diagram as shown below. This location diagram also occurs on pp. 99, 100, and 103.

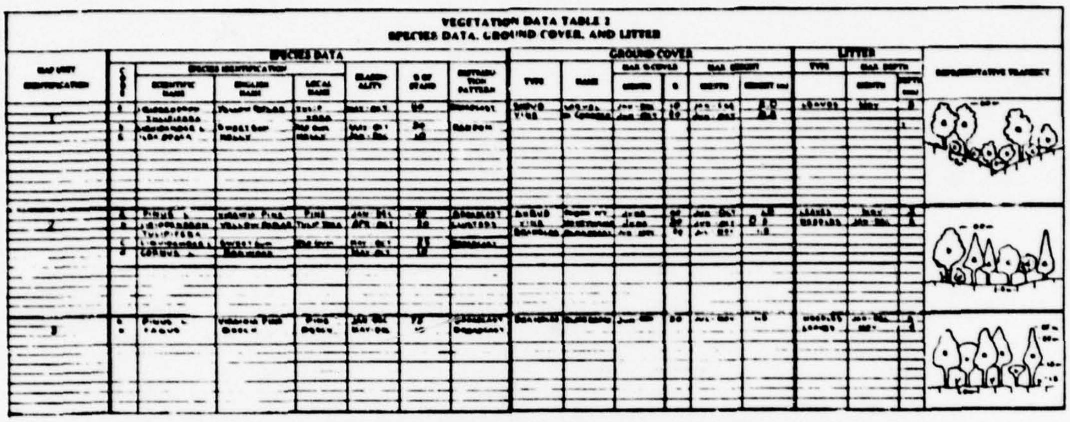
5661 IV
5661 III
5660 IV

Page 11, Substitute the table below for Data Table 1. This table is referred to in whole or in part on pp. 77, 79, 94, and 106.

Vegetation Data Table 1
Stem diameters, Canopy Height and Canopy Closure

Map Unit Identification	Number Stems per Hectare	Mean Stem Diam. (cm)	Stem Spacing (m)	Number, Each Stem Diameter Class per Hectare: <5 (cm)	5-10 (cm)	10-15 (cm)	15-20 (cm)	20-25 (cm)	25-30 (cm)	30-35 (cm)	35-40 (cm)	40-45 (cm)	45-50 (cm)	50-55 (cm)	55-60 (cm)	60-65 (cm)	65-70 (cm)	Mean Height (m): Top of Canopy	Lowest Branches	% Canopy Closure by Season: Dec-Feb	Mar-May	Jun-Sep	Oct-Dec
101	1000	18	1.7		200	67	430	183	210									20	3.0	50	70	100	60
102	312	20	3.2			37	118	75	50	23	9							23	3.2	10	60	90	60
103	313	33	3.1					25	60	100	29							30	4.1	20	30	60	30
104	888	21	1.8			74	170	530	85	29								27	3.5	10	30	100	40

Page 11, Substitute the table below for the lower data table. This table is referred to in whole or in part on pages 85, 89, 91, 96, and 107.



Page 13, change the author of <u>Vegetation Mapping</u> from A.W. Kucher to A. W. Kuchler.

Page 15, last line of paragraph 2; change Appendix C to Appendix C-2.

Page 15, line 5 of paragraph C; change Appendix C to Appendix C-3.

Page 30, line 4 of paragraph 10; change page numbers from 78-80 to 78-82.

Page 32, line 2 of paragraph 16; change page numbers from 95-96 to 95-97.

Page 43, line 3 of paragraph <u>1</u>; change "from" to read "form".

Page 48, line 3 of paragraph 2.a.; change "Table 4" to read "Table 3".

Page 57, after Figure; add ...17.

Page 61, on the lower half of the page; change the expression $r=\sqrt{\underline{a}}$, to $r = \sqrt{\frac{a}{\pi}}$.

Page 62, on lower half of page; below the expression "Radius of 0.08 hectare as measured on the photograph = $\frac{15.96m}{10.5m/mm}$ "add ... = 1.52mm.

Page 87, line 13 of paragraph (d); change "Using" to read "Utility of."

Page 89, substitute the table below for Table 13.

GROUND COVER					
TYPE	NAME	MAX. % COVER		MAX. HEIGHT	
		MONTH	%	MONTH	HEIGHT (m)
SHRUB	LARUEL	JAN-DEC	10	JAN-DEC	2.0
VINE	VA. CREEPER	JUN-OCT	20	JUN-OCT	0.5

Page 91, substitute the table below for Table 14.

MAP UNIT IDENTIFICATION	CODE
1	a
	b
2	a
	b

LITTER		
TYPE	MAX. DEPTH	
	MONTH	DEPTH (cm)
broadleaves	NOV	3
broadleaves		
needleleaves	JAN-DEC	5

Page 118, delete the information in the LOCATION column and substitute that shown below.

FOREST TYPE	LOCATION
Lower Montane	Puerto Rico
Montane	Puerto Rico
Monsoon	Thailand
Xerophytic	Puerto Rico
Rainforest palm	Puerto Rico
Rainforest	Puerto Rico & Dominica, British West Indies
Combination of all forest types	Puerto Rico, Thailand & Dominica, BWI

Page 119, In BASIC REGRESSION EQUATION column; after H = add ... tree height in feet.

Page 154, change the address of the Aerial Photography Field Office to
2222 West 2300 South
P.O. Box 30010
Salt Lake City, UT 84125

Page 154, change the zip code of the Defense Intelligence Agency to... 20301.

Page 154, line 10; change DMAHC to DMAHTC.

Page 154, line 12; change 20335 to 20315.

Page 160, last line; after Washington, D. C. add... 20310.

Page 181, add the reference below to Appendix D-2d:

Kuchler, A. W., International Bibliography of Vegetation Maps, Vol. I - N. America; Vol. II - Europe; Vol. III - U.S.S.R., Asia, Australia; Vol. IV - Africa, S. America, and World Maps, 1966.

Page 195, line 2; delete (Ref.).

Page 196, line 13; delete (Ref.).

Page 202, lines 12 and 13; change Representation Fraction to Representative Fraction.

Page 204, lines 2 and 3; delete...and between tundra.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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Thematic Mapping

403 192 Gur

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This procedural guide provides the U.S. Army Terrain Analyst with the necessary step-by-step procedures to be used in generation of vegetation factor overlays and supportive data tables. Three potential sources of information on vegetation are considered: (1) military topographic maps, (2) literature, and (3) aerial imagery. Procedures are presented for each of 13 data elements that characterize vegetation of the geographic area of interest. The included appendixes provide the Terrain Analyst with additional reference information.

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PREFACE

This Terrain Analysis Procedural Guide for Vegetation, produced under authority contained in Project 4A762707A855, Task C, Military Geographic Analysis Technology, is t~~he first in a~~ series of Terrain Analysis Guides that will be produced during the next 2 years in support of the Military Geographic Information (MGI) subsystem of the Topographic Support System (TSS). Because these guides are intended to be published as Department of Defense Technical Manuals, critical comments and suggestions for improvement are requested by the authors. This work was conducted under ths supervision of Mr. Alexander R. Pearson, Chief, Topographic Products Design and Development Group, MGI Data Processing and Products Division, Geographic Sciences Laboratory.

The authors wish to express their appreciation to Ms. N. E. Kothe, Chief, Scientific and Technical Information Center (STINFO), who supplied needed research materials; to Mr. E. James Books, Editor, Technical Reports Office, STINFO, who provided a valuable technical review and edit; and to Ms. B. A. Jayne, Ms. L. V. Little, and Mr. C. I. Key, Team Leader, Cartographic Support Team, who provided the tables and illustrations for this Guide. Appreciation is also expressed to Messrs. M. B. Satterwhite and M. Treiber, Center for Remote Sensing, who supplied valuable technical assistance.

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TERRAIN ANALYSIS PROCEDURAL GUIDE FOR VEGETATION

I. INTRODUCTION

A. Purpose. The purpose of this report is to provide terrain analysts with step-by-step procedures for collecting and analyzing vegetation information and recording the results in the form of factor overlays. Procedures are provided for the use of three types of sources: maps, literature, and imagery.

B. Background. The first step in the generation of terrain intelligence and preparation of special purpose products is to reduce the data contained in a variety of source materials to a uniform format. This first step of extracting data from available sources, then reducing and recording it in the desired form, is the most laborious and time-consuming step in the production cycle. If the process is delayed until a production requirement is imposed, the response time would be increased. However, if the extracting, reducing, and recording is performed in advance and the preformatted results maintained in the data base, the time required to respond to a production requirement can be greatly reduced. One practical method of producing this information is the factor overlay concept, which records the results of the vegetation analysis for the data base.

In Figure 1, the factor overlay concept for preformatting data is shown in the form of factor overlays registered to standard military topographic maps. Under this concept, data are extracted from various source materials and recorded on factor overlays (Figure 2) and supporting data tables (Figure 3). Separate overlays and tables are prepared for each map sheet for each major terrain subject or data field, e.g. surface materials, surface configuration, vegetation, drainage, and roads. Factor overlays and tables are intermediate data base products intended primarily as tools for the terrain analyst and are not customarily distributed outside of the topographic and intelligence community.

Factor overlays are used in various combinations to generate factor complex maps that become, in effect, the manuscripts for special purpose products, such as cross-country movement, fields of fire, IPB (Intelligence Preparation of the Battlefield) graphics, etc. The data elements appearing on complex maps become inputs for analytical performance prediction models. For example, preparation of a cross-country movement (CCM) map would begin by combining the overlays for surface configuration, surface materials, and vegetation into a complex map. Those data elements affecting CCM, i.e. slope, stem spacing, stem diameter, soil strength etc., are then recorded in the complexed areas of the map. When processed by analytical models, these elements are transformed into vehicle speed predictions for each complexed area.

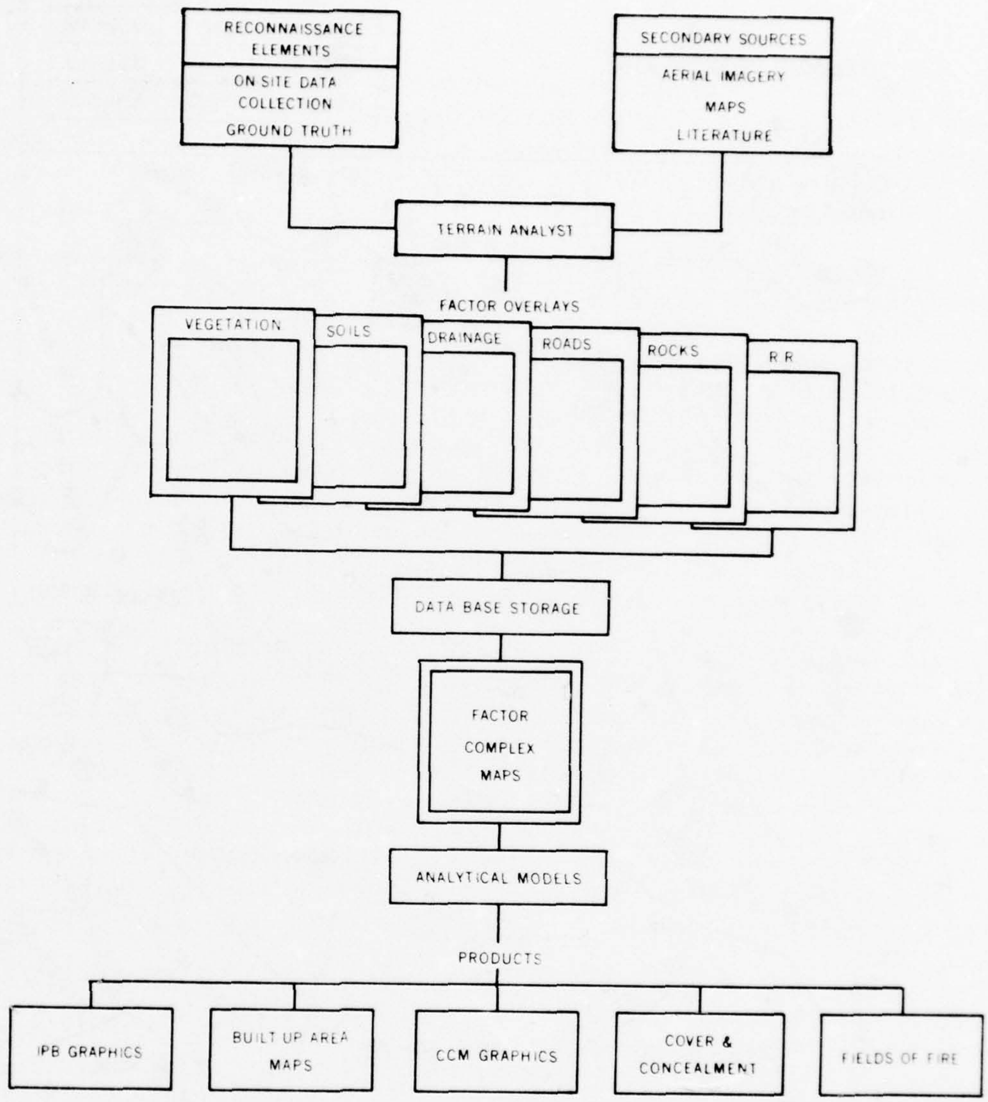


FIGURE 1. Production and Use of Factor Overlays and Data Tables

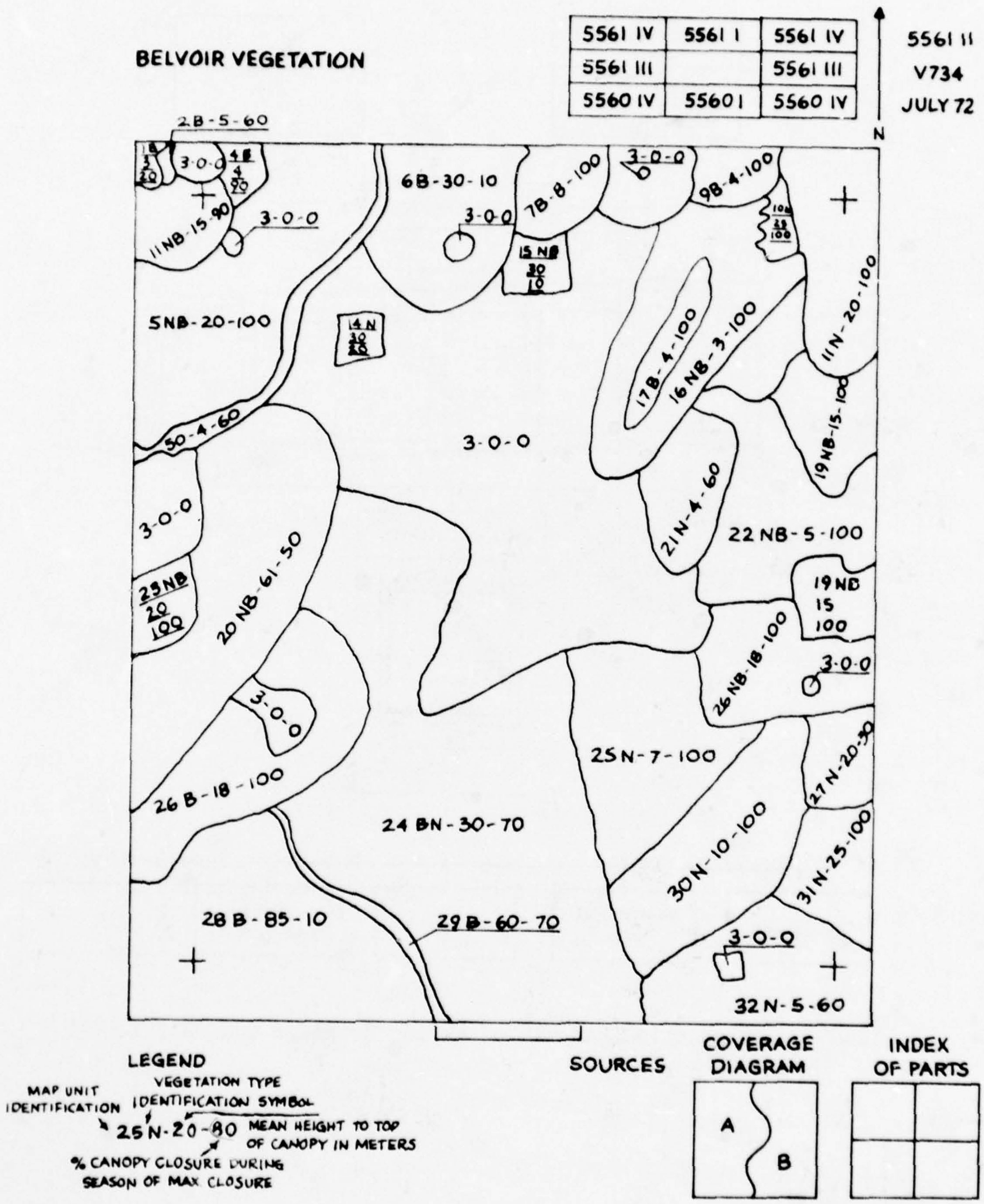


FIGURE 2. Sample Factor Overlay

VEGETATION DATA TABLE I STEM DIAMETERS AND HEIGHT OF CANOPY			NUMBER, EACH STEM DIAMETER CLASS PER HECTARE																									MEAN HEIGHT		CANOPY CLOSURE BY SEASON			
MAP UNIT IDENTIFICATION	TOTAL STEMS/ HECTARE	MEAN STEM DIAM (cm)	<1 (cm)	1-2 (cm)	2-3 (cm)	3-4 (cm)	4-5 (cm)	5-6 (cm)	6-7 (cm)	7-8 (cm)	8-9 (cm)	9-10 (cm)	10-12 (cm)	12-14 (cm)	14-16 (cm)	16-18 (cm)	18-20 (cm)	20-25 (cm)	25-30 (cm)	30-35 (cm)	35-40 (cm)	40-45 (cm)	45-50 (cm)	50-60 (cm)	60-70 (cm)	70-80 (cm)	80-100 (cm)	TOP OF CANOPY (m)	LOWEST BRANCHES (m)	DEC-FEB	MAR-MAY	JUN-AUG	SEP-NOV
[illegible]	2000	3.7		82						200			22	16	28		20	80	50	100		8		3				20	2	[illegible]	[illegible]	[illegible]	[illegible]
2	675	9							130			210	50					120				110			16			35	3.5				
4	300	11.4								3				90				30		20			100			25		75	4	[illegible]	[illegible]	[illegible]	[illegible]
5	450	11							15			190		80		65		30	50	210								25	5				
[illegible]	313	14					125	50			22				75	120		50			85	110						40	3	[illegible]	[illegible]	[illegible]	[illegible]
7	337	20											75	10	42		250		80	[illegible]			115	22	55			71	[illegible]				
8	300	20.5				5												9			10	10		140			35	35	5	[illegible]	[illegible]	[illegible]	[illegible]
9	1665	17.8			84				200		11		28		15			210	80		150	100		8	3			50	3				
10	350	14.5					180		40			125	70			125		45		220						75		45	3.5				
12	875	28.4						81		110	210			50			120		50		50		110	110	25	15		26	3.5				
13	530	5					50		5				96															65	[illegible]				
14	310	10		75	133		40	220		60	114		175	60	35													3	1.75				
15	275	5		15	290	40	114	60			15		85				60	118										1	[illegible]				
[illegible]	735	5		260		80	15		109	40		60				95												5	1.5				
[illegible]	675	15						130			210			50			120			110				75				35	7.5				
[illegible]	550	9		75		120	40			125	175			77		15		377										5	2				

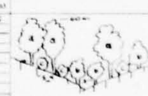
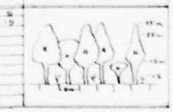
VEGETATION DATA TABLE SPECIES DATA, GROUND COVER, AND LITTER	SPECIES DATA							GROUND COVER						LITTER			
		SPECIES IDENTIFICATION								MAX. % COVER		MAX. HEIGHT		TYPE	MAX. DEPTH		
MAP UNIT IDENTIFICATION	CODE	SCIENTIFIC NAME	ENGLISH NAME	LOCAL NAME	SEASONALITY	% OF STAND	DISTRIBUTION PATTERN	TYPE	NAME	MONTH	%	MONTH	HEIGHT (m)		MONTH	DEPTH (cm)	REPRESENTATIVE TRANSECT
1	a	LIRIODENDRON TULIPIFERA	YELLOW POPLAR	TULIP TREE	MAY-OCT	50	BROADCAST	SHRUB	LAUREL	JAN-DEC	5	JAN-DEC	2	LEAVES	NOV	25	
							RANDOM	VINE	VA CREEPER	JUN-OCT	20	JUN-OCT	20				
	b	LIQUIDAMBAR L.	SWEET GUM	RED GUM	MAY-OCT	30											
	c	ILEX OPACA	HOLLY	HOLLY	JAN-DEC	10											
2	a	PINUS L.	VIRGINIA PINE	PINE	JAN-DEC	40	BROADCAST	SHRUB	POISON IVY	JUNE	40	JUN-OCT	1	LEAVES	NOV	25	
	b	LIRIODENDRON TULIPIFERA	YELLOW POPLAR	TULIP TREE	APR-OCT	20	CLUSTERS	VINE	HONEYSUCKLE	JUNE	35	JUN-OCT	.5	NEEDLES	JAN-DEC	5	
							BROADCAST	BRAMBLES	BLACKBERRY	JUN-NOV	20	JUL-NOV	1.5				
	c	LIQUIDAMBAR L.	SWEET GUM	RED GUM	MAY-OCT	25											
	d	CORNUS L.	DOGWOOD		MAY-OCT	10											
3	a	PINUS L.	VIRGINIA PINE	PINE	JAN-DEC	75	BROADCAST	BRAMBLES	BLACKBERRY	JUN-NOV	50	JUL-NOV	1.5	NEEDLES	JAN-DEC	5	
	b	FAGUS	BEECH	BEECH	MAY-DEC	10	BROADCAST							LEAVES	NOV	5	

FIGURE 3. Sample Data Tables

The vegetation product, as envisioned by this guide, is a factor overlay with supporting data tables, which will become part of the data base described above. The source materials used in preparation of the factor overlay for vegetation will include those given in Figure 1. The amount and type of data collected will depend on the analyst's training and education, amount of reference literature available, geographic region, and the type and scale of the aerial imagery that can be obtained.

C. Data Elements

Titles of the data elements included in the vegetation data base are listed below. Detailed requirements for each element are contained in Appendix A.

Vegetation Area Boundaries

Area Identification

Vegetation Type

Height to Top of Canopy

Canopy Closure

Stems per Hectare

Stem Diameter

Stem Spacing

Species

Ground Cover

Litter

Height to Lowest Branches

Representative Transect

Seasonality

D. Suggested Reading

Since the Army is required to operate in all parts of the world, detailed worldwide information on vegetation is needed. To obtain this information, the terrain analyst must have at least a limited knowledge of the distribution of plant communities and the factors affecting the growth habits of plants within these communities. Additionally, the

analyst is required to have a working knowledge of the methods used to obtain vegetation information from maps, scientific literature, and various types of aerial imagery. It is suggested, therefore, that the analyst read and review the following texts:

Vegetation Mapping
A. W. Kucher
The Ronald Press Company, New York
1967

Interpretation of Aerial Photographs
T. E. Avery
2nd Edition
Burgess Publishing Company, Minneapolis, Minnesota
1968

Aerial Photographs in Forestry
S. H. Spurr
The Ronald Press Company, New York
1948

II. SOURCE MATERIALS

Normally, no single source document is capable of providing all of the vegetation data required for the complete vegetation factor overlay and data tables. In most cases, the analyst must use different sources for different geographic areas and, in many cases for different data elements within a single map sheet. Occasionally, incomplete source material must be used. In addition, material from foreign sources must be used, which sometimes presents problems in translation, definitions, etc. As better sources become available, first generation overlays will be revised to incorporate the additional information. In some cases, there will be areas for which no sources are readily available. When such areas are found, a collection effort must be initiated to obtain suitable source material. In this section, the principal sources available to an analyst are discussed.

A. Maps. In general, three major map types are available to the terrain analyst that can be used to obtain the data required for compilation of the vegetation overlay. These maps are characterized in the following paragraphs.

1. Military Maps. Standard military topographic maps that portray vegetation data are available at a number of scales. The maps differ in completeness according to scale and country of origin. Table 1 presents the type of vegetation data that can usually be obtained from maps produced by the United States (U.S.), Union of Soviet Socialist Republic (U.S.S.R.) and the Federal Republic of Germany (FRG). The vegetation units (where applicable) depicted on these maps can be adjusted for scale and transferred to the map overlay and to the appropriate data tables in accordance with the specifications presented in Appendix A.

TABLE 1. MAP CAPABILITIES FOR VEGETATION DATA ELEMENTS

DATA ELEMENT	UNITED STATES 1:250,000	UNITED STATES 1:50,000	FEDERAL REPUBLIC GERMANY 1:250,000	FEDERAL REPUBLIC GERMANY 1:50,000	USSR 1:200,000	USSR 1:50,000
1. Map unit identification/ Vegetation boundaries	Limited to major veg. boundaries	Limited to major veg. boundaries	Limited to major veg. boundaries	Limited to major veg. boundaries	Limited to major veg. boundaries	Limited to major veg. boundaries
2. Mean height to top of canopy	Woodland >3m Scrub <3m	Woodland >3m Scrub <3m	No	No	Yes	Yes
3. % canopy closure by season	Limited est for maj veg type	Limited est for maj veg type	Limited	Limited	Limited	Limited
4. Number of stems per hectare	No	No	No	No	No	No
5. Crown diameter	No	No	No	No	No	No
6. Mean stem diameter	No	No	No	No	Yes	Yes
7. Number of trees in each stem diameter class per hectare	No	No	No	No	No	No
8. Stem Spacing	No	No	No	No	Yes	Yes
9. Species identification, seasonality, and distribution	No No No	No No No	Coniferous Deciduous Mixed only	Coniferous Deciduous Mixed only	Coniferous Deciduous Mixed only	Coniferous Deciduous Mixed only
10. Gound cover type, % of cover, and height	No	No	No	No	No	No
11. Litter type and depth	No	No	Limited	Limited	Limited	Limited
12. Mean height to lowest branches	No	No	No	No	Limited	Limited
13. A representative transect	No	No	No	No	No	No

2. Small-Scale Vegetation Maps (1:1,000,000). This type of map can be found in any general geography text and usually depicts very broad categories of vegetation. In general, these maps and associated descriptions do not provide the detail of information that is required in Appendix A. However, they should be reviewed by the analyst for familiarization with tree and plant species of the geographic area of interest. A partial list of existing maps arranged alphabetically by country is provided in Appendix C (Vegetation Maps).

3. Species Distribution Maps. These maps are produced under a variety of names depending on the type of data they present. For example, maps of this type produced by the U. S. Forest Service are called Type Forest Inventory Maps, or Timber Management Maps. Commercial lumber companies produce maps of a similar nature. Also, colleges and universities produce similar maps but most contain more detailed information on vegetation other than tree species. In general, species maps can be characterized by their large scale, small area of coverage, and large amounts of detailed information. Because they are produced for a limited function and area, they are difficult to locate and reproduce. When available, however, they provide an excellent source of information; most of them include all of the vegetation data required in Appendix A. In addition, this type of map can be utilized by the Terrain Analyst as an aid in the interpretation of aerial imagery by expanding information provided by the map to areas of terrain not covered by the map. The analyst is encouraged to query local government agencies and universities located in the geographic region of interest.

B. Literature. This source of information (Appendix D, Supplementary References) is nearly unlimited in quantity, scope of subject matter, and coverage of geographic regions of the world. Unfortunately, information available from this source is usually too general to be of much use to the Terrain Analyst. It will provide an understanding of the major forest and plant communities that are found in given areas of the world and, for this reason, should be reviewed by the analyst as background source material. The best literature (i.e. reports, articles, and textbooks) that will supply the specific information needed by the analyst can be obtained from local government agencies, universities, libraries, and commercial lumber companies.

C. Aerial Imagery. As used in this procedural guide, aerial imagery includes imagery obtained with any of the following remote sensor systems: aerial cameras, electro-optical scanners, and radar. Imagery acquired from each of these systems can provide some, if not all, of the information required for the vegetation overlay (see Appendix C, Aerial Imagery Sources). The accuracy and amount of detail that can be obtained will depend on the type and scale of the imagery as well as the skill and knowledge of the analyst. Each of the above sensor systems have individual characteristics and capabilities as specified on the following pages.

1. Aerial Cameras. Vertical aerial photography is very important to the analyst because, properly utilized, it is the most complete source of information available when acquired at scales larger than 1:20,000. There are four film types that are generally available: color, color infrared, black and white infrared and panchromatic photography. Figure 4 delineates those regions of the electromagnetic spectrum to which each of these film types is sensitive. During aerial acquisition flights, these films are exposed in such a manner that each exposure overlaps the preceding one by approximately 60 percent with adjacent flight lines overlapping 30 percent. With this method of exposure, the analyst is given an opportunity to view the photography stereoscopically. Since time of year, sun angle, weather conditions, and film-filter type can affect not only quality of the photography but also tonal renditions of the image, the analyst should be aware of these characteristics if a correct analysis is to be produced. For example, in temperate climates, during September and October, the color of most deciduous trees and shrubs change from day-to-day. Aerial photography acquired during these months will also have tonal qualities that will vary daily.

The image tonal quality or color of a vegetation type also depends on the type of film and film-filter combination employed. A stand of spruce trees, for example, will appear as a medium gray tone on panchromatic film, dark gray on black and white infrared film, dark green on color film, and dark red on color infrared film. When using aerial imagery to obtain vegetation data, the analyst must be aware of these film characteristics to produce an accurate analysis.

Under normal conditions there are small differences in the scale of adjacent aerial photographs caused by minute changes in the aircraft's altitude and attitude during exposure of each photograph. Additional changes in photo scale are created by changing terrain elevations as the aircraft proceeds along the flight line at a constant altitude. These variances in scale require that the analyst continually check the scale of the photograph by comparing photograph scale with corresponding map scale.

Additional information on the interpretation of vegetation from aerial photography is provided in Appendix D-2e.

2. Electro-Optical Scanners. Multispectral and thermal infrared scanners combine both optics and electronics to produce aerial imagery. The imagery produced by these systems has characteristics which differ markedly from aerial photography. In operation, the scanner employs a rotating mirror to collect reflected and/or emitted energy from the terrain into a series of detectors that change light energy into electric energy. This energy is then recorded directly on either film or magnetic tape (Figure 5). With either method of recording the analyst is provided with hard copy imagery

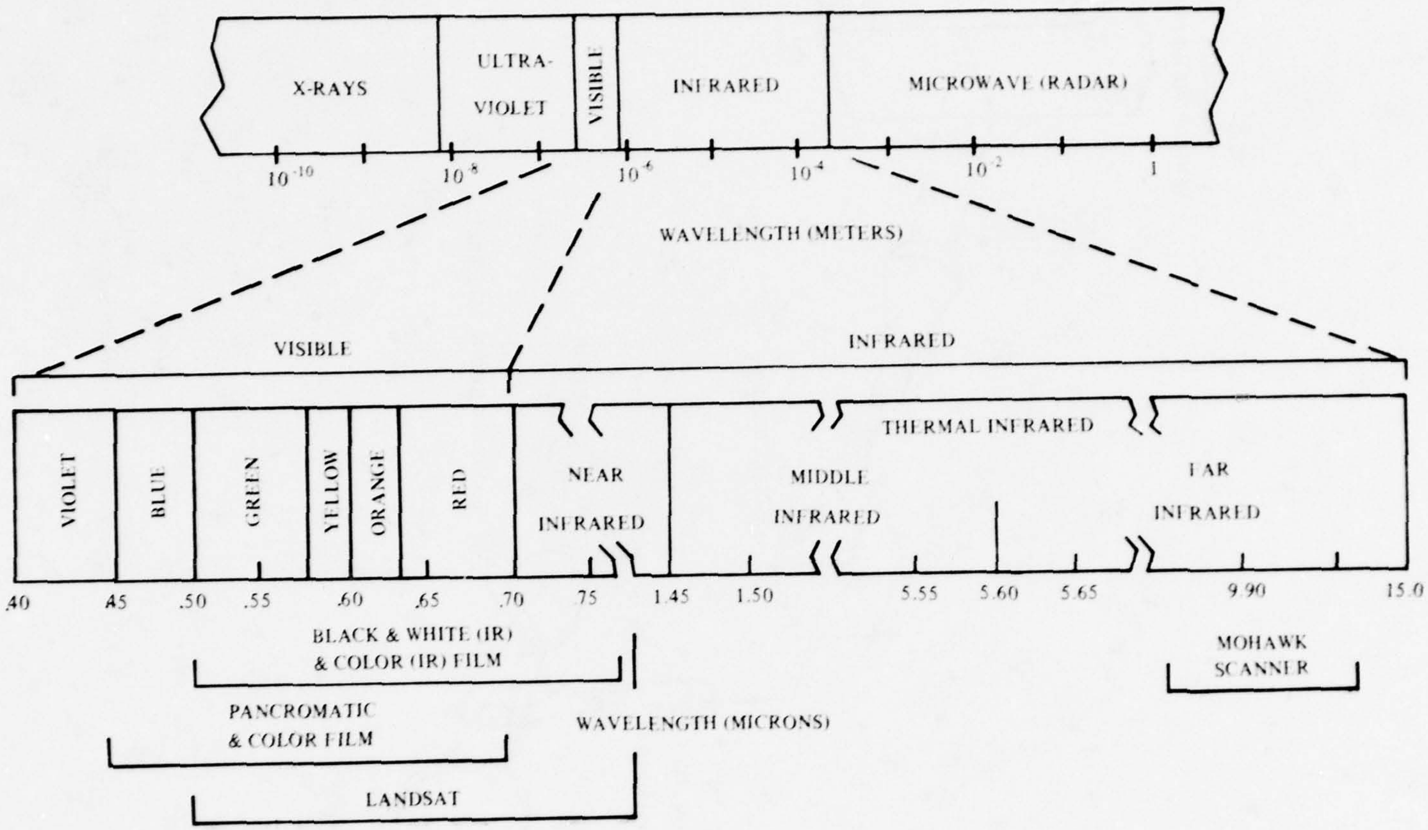


FIGURE 4. The Electromagnetic Spectrum

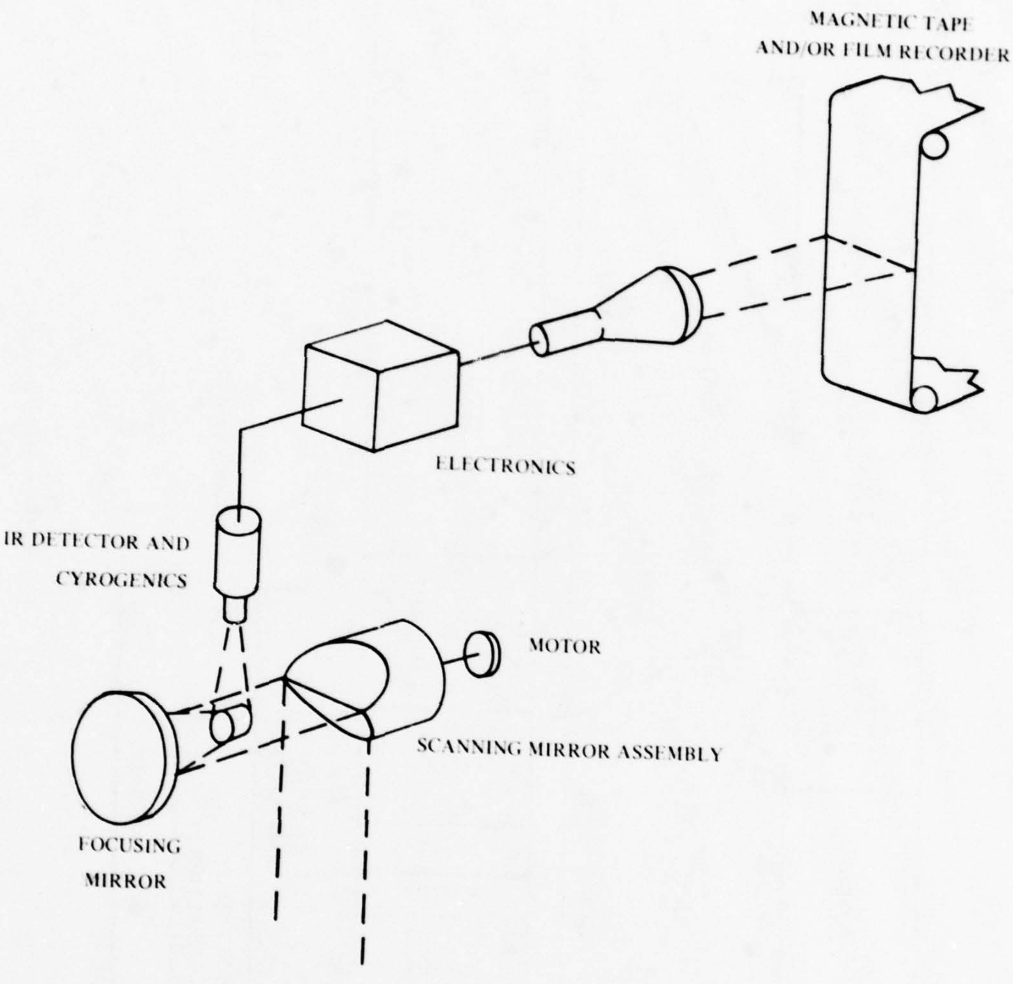


FIGURE 5. Schematic of Infrared Scanner

that can be employed to produce vegetation maps. Normally, scanner imagery is produced in a continuous strip that depicts the terrain with a series of continuous scan lines (Figure 6). This method of image acquisition limits the utility of scanner imagery, since stereo viewing of the imagery is impossible and (because of the scanning mirror) image scale variation is considerable. The problem of varying scale, however, can be reduced by analyzing only the very center portion of each image.

The spectral sensitivity of a scanner system is dependent on the type and number of detectors used in the system. The U. S. Army Mohawk aircraft scanner system is limited to the thermal infrared portion of the electromagnetic spectrum; however, the LANDSAT satellite contains a multispectral scanner that is sensitive to the green, red, and near-infrared portions of the spectrum (Figure 4). Other scanners are available that are sensitive to energy that ranges from ultraviolet to the thermal infrared region of the electromagnetic spectrum.

3. Radar. Radar remote sensor systems are composed of three subsystems that include; (1) a transmitter, (2) a receiver, and (3) a ground-based optical correlator that translates data produced by the system into hard copy imagery. Radar systems, including SLAR (Side Looking Airborne Radar) and SAR (Synthetic Aperture Radar), are considered to be active rather than passive systems because they do not rely on reflected solar energy for operation. With few exceptions, the radar sets used today are synthetic aperture radar (SAR) which in general have greater resolution capabilities than brute-force or fixed antenna radars.

An analysis of radar imagery is more complex than aerial photography because of the geometric characteristics of radar systems, the small scales used, and the patterns that are presented on a radar image, which are not directly comparable to the patterns on an aerial photography. In addition, the scale of a radar image in the along-track direction is different from the across-track direction. The along-track scale is constant, however, the across-track scale varies with the distance from the ground track of the aircraft (Figure 7). The Image Interpretation Handbook should be reviewed before attempting any measurement from radar imagery.[1]

Radar systems are also classified by both frequency and wavelength. Though the terrain analyst does not always have the opportunity to select the type and scale of imagery, X-, Ku-, and Ka-band radars provide the best imagery for obtaining vegetation data (Figure 8). With experience, the terrain analyst should be able to obtain estimates for vegetation height, type, and stem density.

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[1]U. S. Army, "The Image Interpretation Handbook," TM 30-245, December 1967.

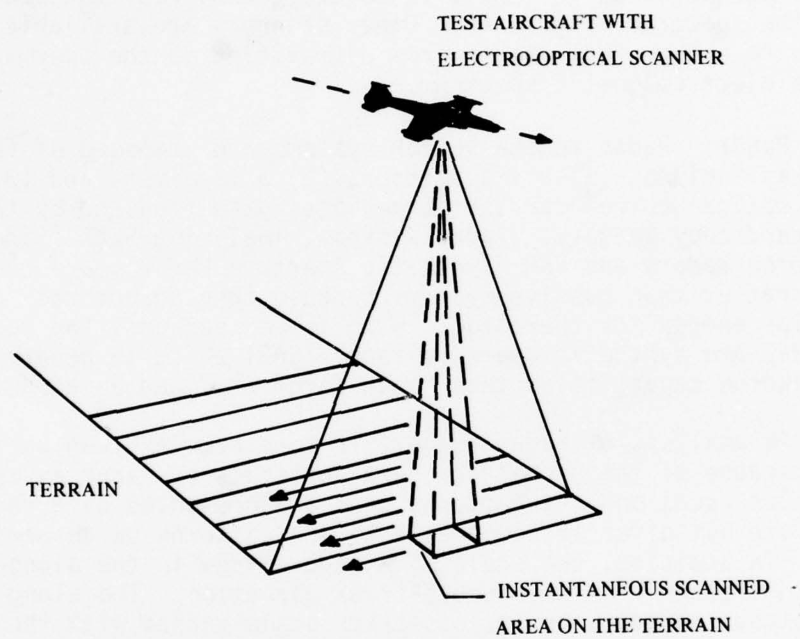


FIGURE 6. Geometry of Electro-Optical Scanner Imagery

TABLE 2. AERIAL IMAGE CAPABILITIES FOR VEGETATION DATA ELEMENTS

DATA ELEMENT	AERIAL CAMERAS SCALES >1:20,000	THERMAL AND MULTISPECTRAL SCANNERS	RADAR
1. Map unit identification/ Vegetation boundaries	Yes - Dependent on experience of analyst.	Yes - Dependent on experience of analyst.	Yes - Dependent on scale and type of radar.
2. Mean height to top of canopy	Yes - Stereo photography required	Estimate only	No - Estimate only
3. % canopy closure by season	Yes - Difficult when shadow areas are dark.	Possible but difficult.	No
4. Number of stems per hectare	Yes	Yes	No - Estimate only
5. Crown diameter	Yes	Yes	No
6. Mean stem diameter	Yes - Obtained from crown/ stem diameter relationship	Yes	No - Estimate only
7. Number of trees in each stem diameter class per hectare	Yes	Yes	No
8. Stem Spacing	Yes - Derived from photo-measurable parameters	No	No
9. Species identification, seasonality, and distribution	Separation of needleleaf from broadleaf; species identification difficult.	Separation of needleleaf from broadleaf; species identification difficult.	No
10. Ground cover type, % of cover, and height	% Cover and Height possible; type identification difficult.	% Cover and Height possible; type identification difficult.	No
11. Litter type and depth	Estimated from type of vegetation and geographic area.	Estimated from type of vegetation and geographic area.	No
12. Mean height to lowest branches	Estimate from vertical photo; measurable from oblique photo.	Estimate only	No
13. A representative transect	Possible - Dependent on scale and experience of analyst.	No	No

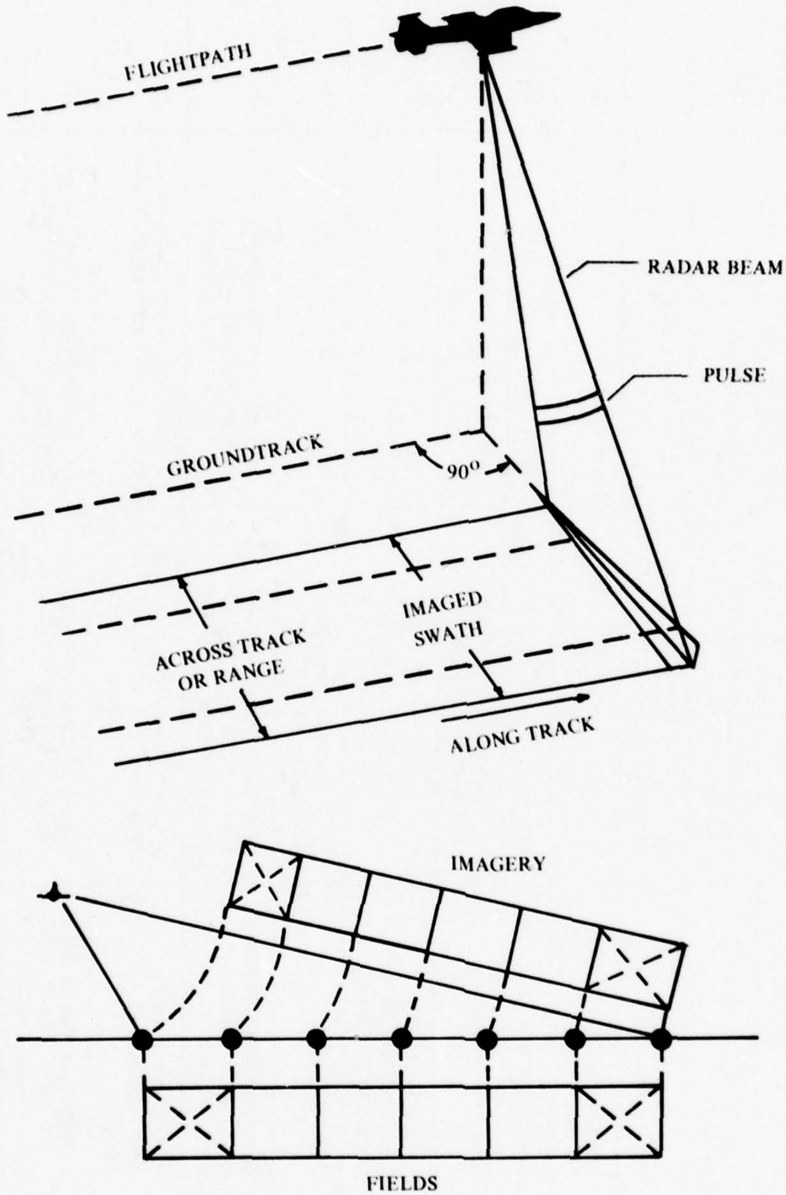


FIGURE 7. Schematic of Radar Geometry Showing Variance in Cross and Along Track Scale

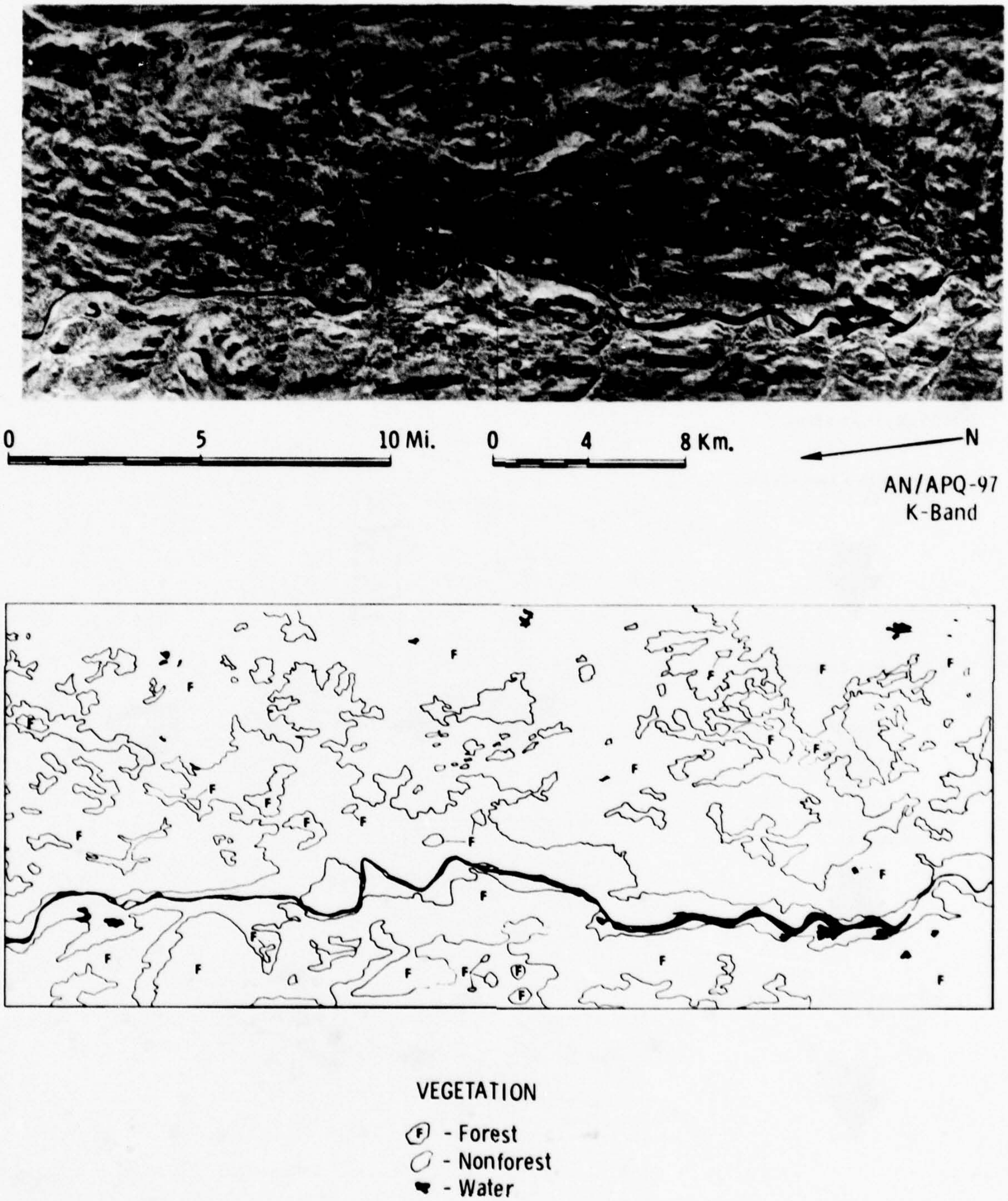


FIGURE 8.
Types of Vegetation Data Obtainable from Radar Imagery.

III. PROCEDURAL OUTLINE

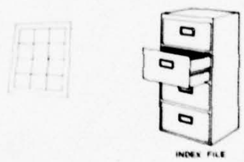
This section provides an overview of the step-by-step procedures required to perform a complete vegetation analysis. The Outline is presented as a schematic flow diagram showing what analyses are required and the sequence in which they are normally performed. The diagram indicates what is to be done; how it is done is explained in the Analysis Procedures Section. References to the appropriate paragraphs are provided in the diagram.

Although the diagram illustrates many separate steps for the purpose of clarity, it will often be more practical to combine two or more of the steps into a single operation.

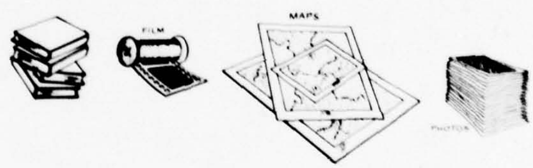
FLOW DIAGRAM

A. PREPARATORY STEPS

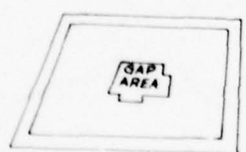
1. Review Data Base Indexes.
   Ref. page 13



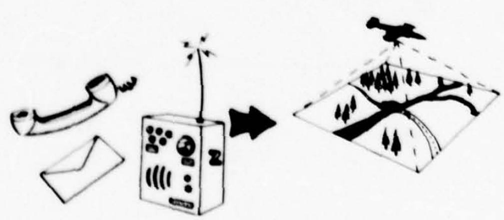
2. Evaluate and select sources.
   Ref. pages 14, 20, 33



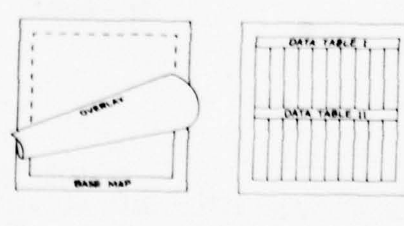
3. Identify Information Gaps
   Ref. page 33



4. Submit Collection Requirement
   Ref. page 33

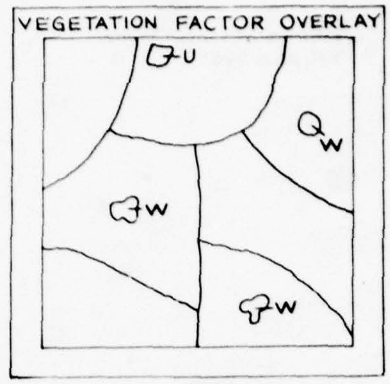


5. Prepare Factor Overlay and Data Table Worksheets.
   Ref. pages 34, 98-109

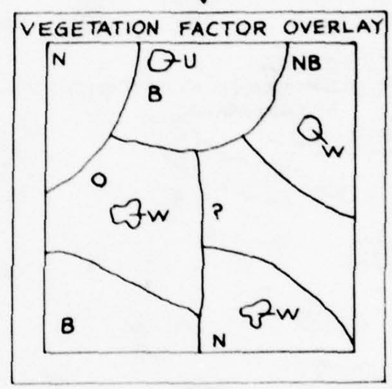


B. MAP ANALYSIS

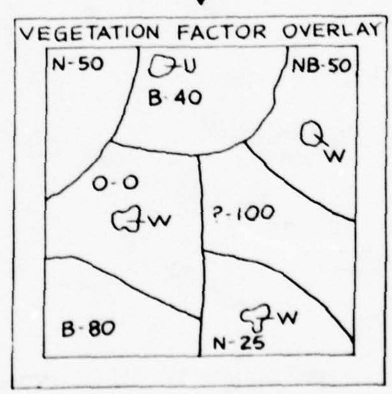
1. Trace vegetation boundaries, open water, agricultural and urban areas from map. Check to insure that all areas are considered and there are no unexplained gaps.
   Ref. pages 34-35



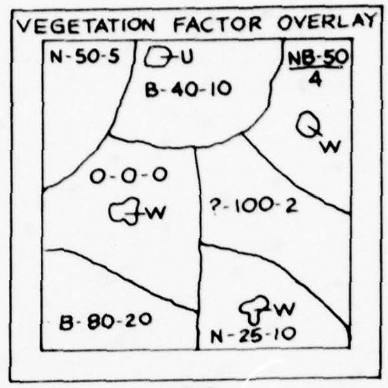
2. Estimate vegetation types and species if shown.
   Ref. pages 36-42



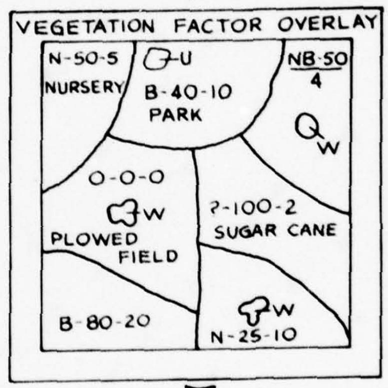
3. Estimate height to top of canopy.
   Ref. pages 14, 48-50, tables 3, 4, 5.



4. Estimate % Canopy Closure.
Ref. pages 54-55



5. Note special conditions from map and literature that will help later analysis.



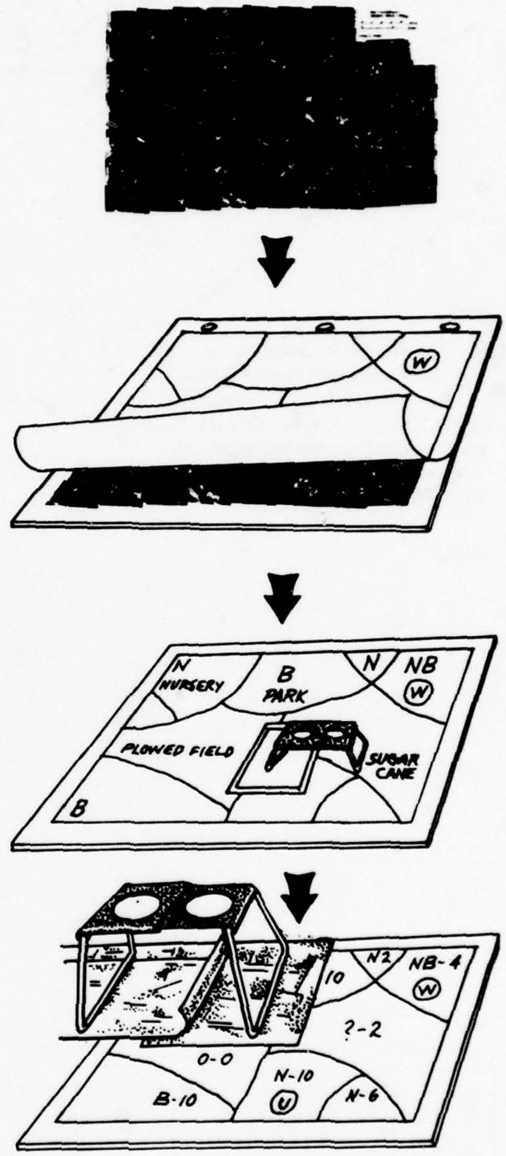
C. PHOTO ANALYSIS

1. Prepare Mosaic from alternate photos. Ref. pages 43, 44

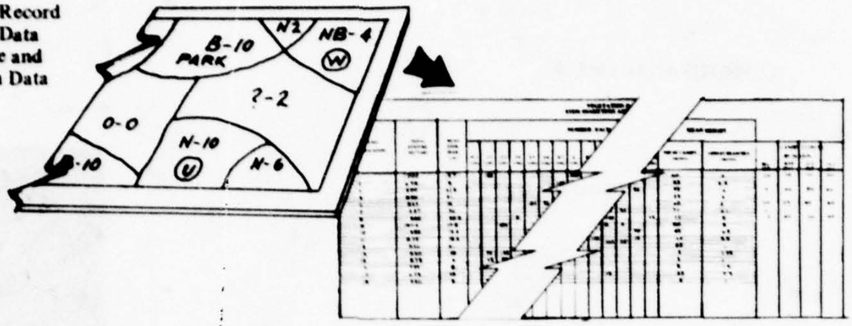
2. Place overlay over Mosaic and outline vegetation, agriculture, water, and built-up areas. Ref. page 44

3. Examine stereoscopically and determine vegetation types. Revise vegetation boundaries and record type on overlay. Note appropriate comments. Ref. pages 44-48

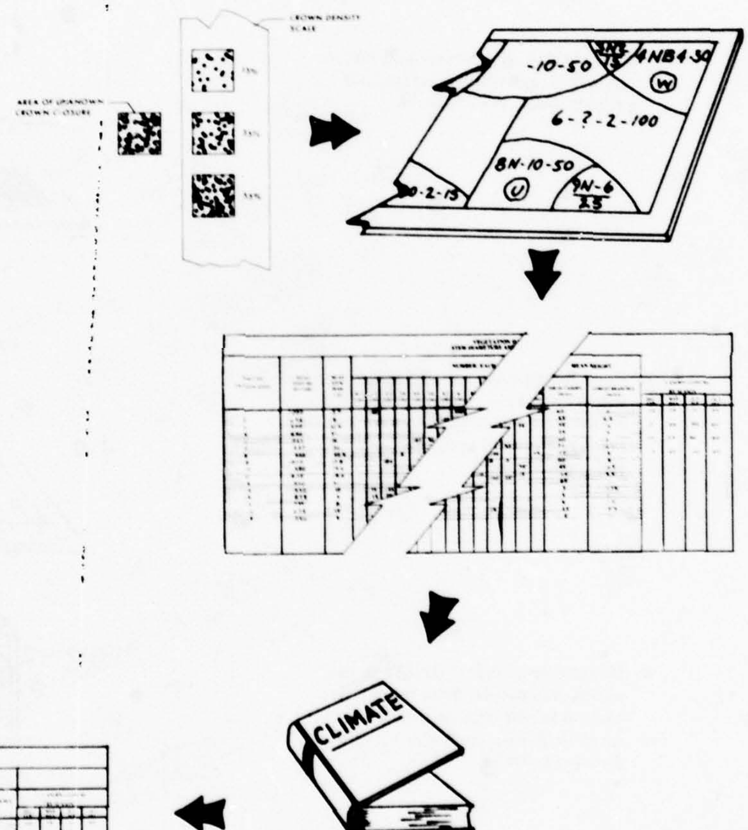
4. Measure heights and classify in two meter increments, draw boundaries around height class areas and record mean height for each area on overlay. Ref. pages 48-54

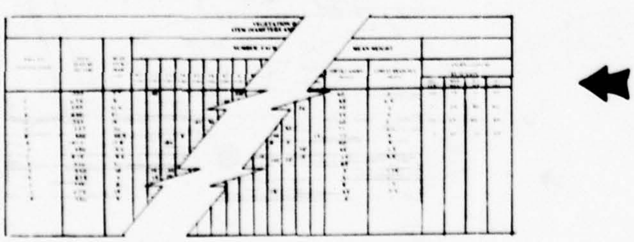


5. Assign map unit area numbers. Record area numbers on overlay and in Data Table 1. Record vegetation type and mean height to top of canopy in Data Table 1. Ref. page 58

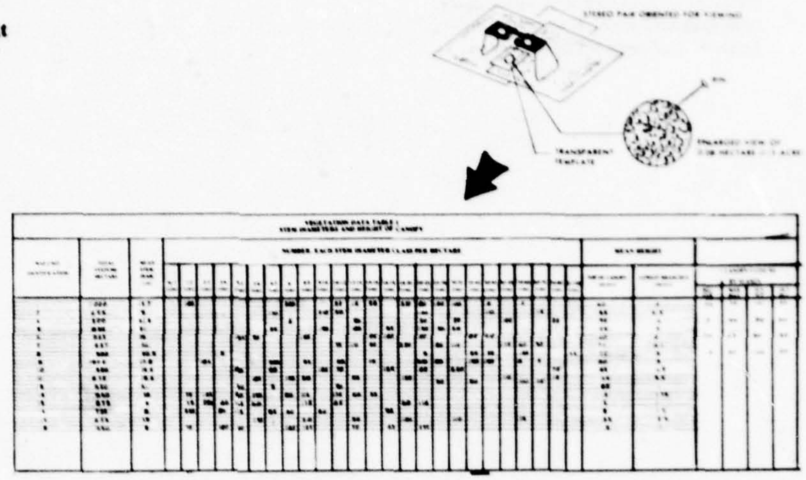


6. Use Crown Density Scale and measure Crown Density on imagery for each map unit area. Record on overlay and in Data Table I. Refer to Climatic Data and estimate seasonality based on earliest and last frost. Record results in Data Table I. Ref: Pages 54-58.



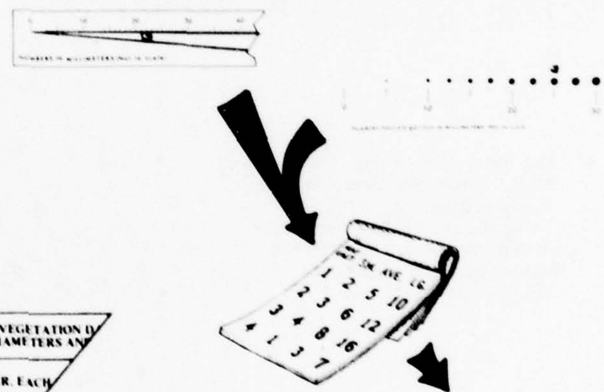


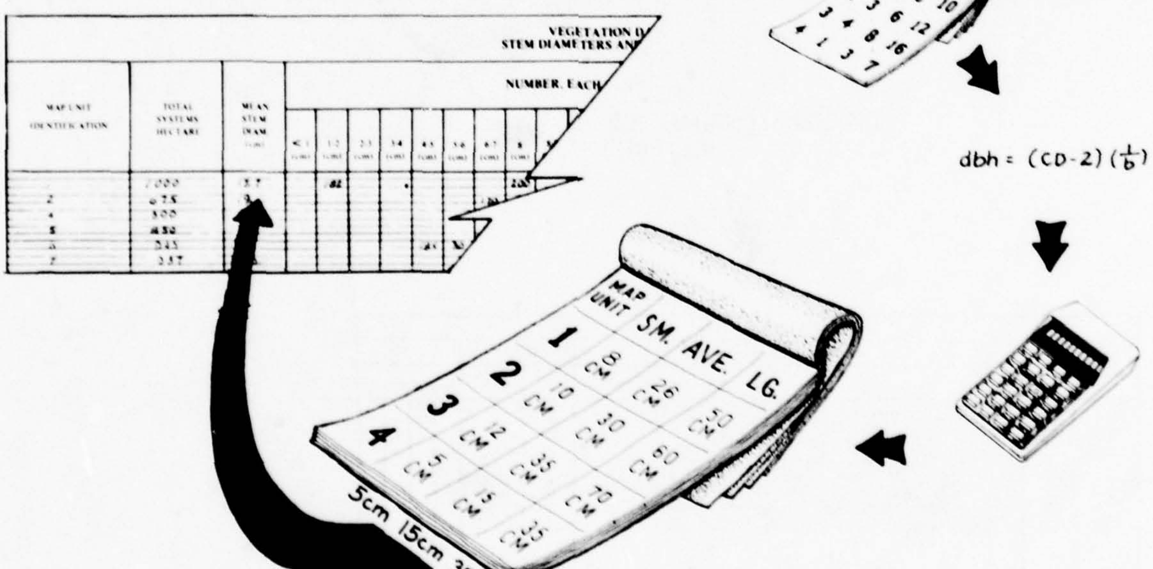
7. Use template with circle of known area on photos. Count crowns within circles and determine stems per hectare (10,000m^2). Repeat for each map unit area and record in Data Table I. Ref: pages 59-69.



8. Use Crown Diameter Scales and determine smallest average, and largest crown diameters within each map unit area. Record in notes for later use. Ref. pages 69-73

9. Use appropriate formula to convert crown diameters to stem diameters (dbh). Record dbh for smallest, average, and largest in notes. Record average dbh in Data Table 1 under "Mean Stem Diameter." Ref. pages 74-77



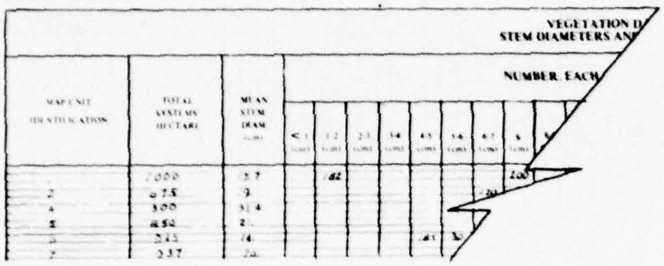


10. Use stems per hectare and mean stem diameter to compute stem spacing for each map unit area. Record in Data Table 1. Ref. pages 78-80

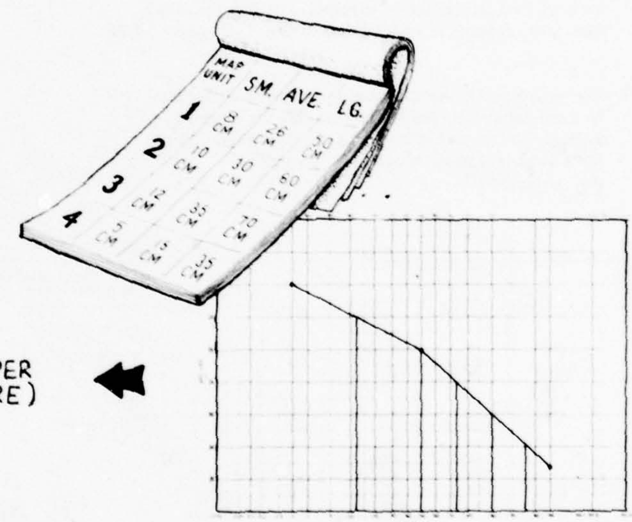
NO STEMS PER HECTARE (N)

MEAN STEM DIAMETER (dbh)

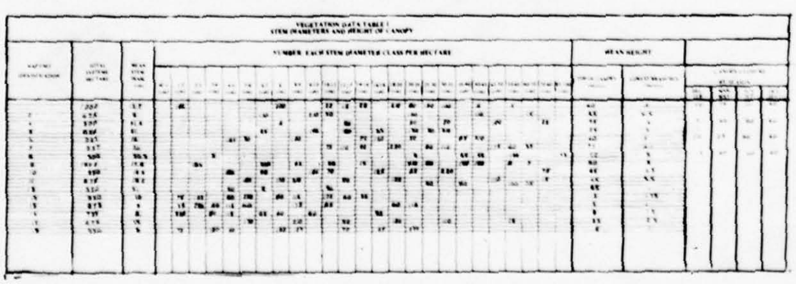
$$S = \sqrt{\frac{12732.4}{N}} - (dbh)$$



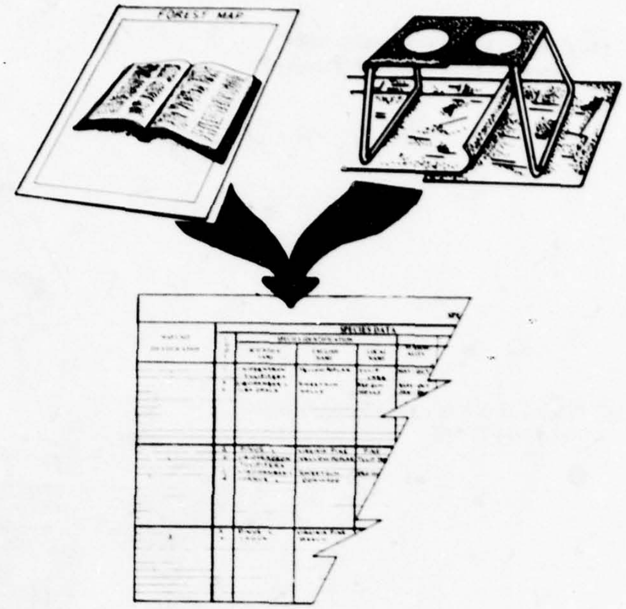
11. Plot the smallest, average and largest dbh on probability paper and determine percentage of trees in each diameter class. Multiply percentage of stems per hectare to determine number in each diameter class. Ref. pages 80-82



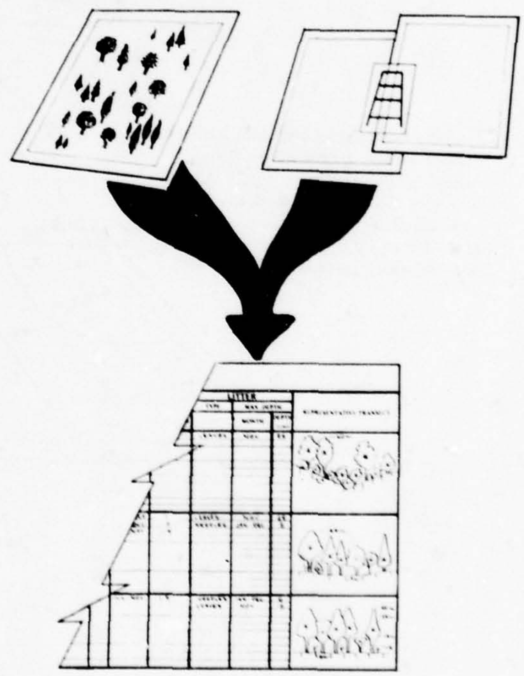
(%/dbh)×(STEMS PER HECTARE)



12. Review documents. Examine each area stereoscopically and identify species. *Estimate* % of map unit area for each species, seasonality, and distribution pattern. Record in Data Table 2. Ref: pages 84-88.



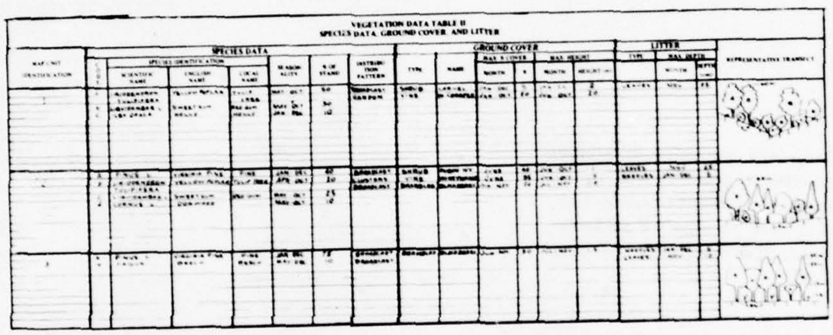
13. Study each map unit area carefully and estimate ground cover type, height, and percent of cover. Use obliques of woodlines if available. Record in Data Table 2. Ref: pages 87-89.



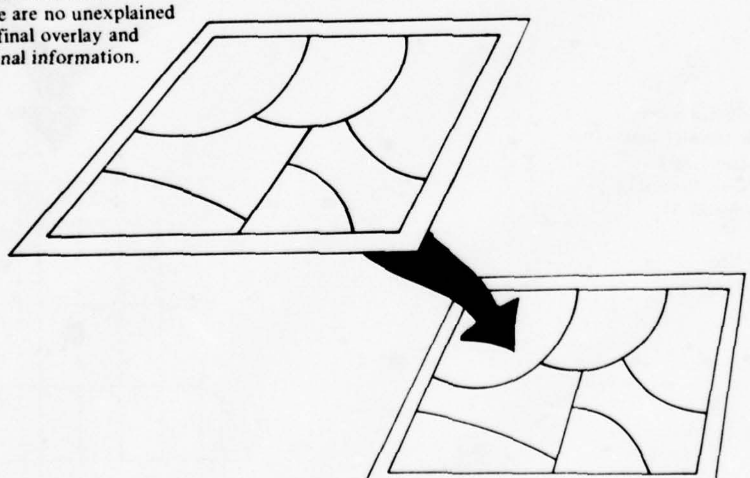
14. Consider vegetation types, species, ground cover, climate, forestry practices, agricultural practices, and estimate litter conditions. Record in Data Table 2. Ref: pages 89-91.

15. **Estimate height to lowest braches. Record in Data Table I. Ref: pages 91-93.**

16. Prepare sketch of representative transect. Ref. pages 95-96



17. Transfer boundaries and data from the mosaic overlay to the map overlay. Adjust boundaries as required. Check to insure that all areas have been considered and there are no unexplained gaps. Clean up the final overlay and add necessary marginal information.



IV. ANALYSIS AND INTERPRETATION PROCEDURES

A. General. This section provides the detailed instructions for extracting each data element from each of the principal sources. Although separate procedures are provided for preparation of vegetation factor overlays from military topographic maps, literature, and aerial photography, it is strongly suggested that the terrain analyst review and use all available data sources in the overlay and data table production process.

In this section, only the basic procedures are discussed. The publications listed in Appendixes B and D-2 should be used to supplement the procedures contained in this guide.

B. Acquisition of Source Materials: In general, all items that provide the analyst with information on plant communities of the area of interest are source materials. Locating these materials will often require a comprehensive search of libraries, government agency files, university research data, and logging or lumber company files. In addition, source materials dealing with vegetation of the geographic area of interest may be found by reviewing the data base file indices as well as information found in Appendix B. Useful materials include current 1:50,000 scale maps; studies, reports, etc.; reconnaissance and image interpretation reports and the largest scale aerial photography that can be obtained.

Review the materials obtained and determine whether they are adequate for generation of the vegetation factor overlay. If they do not provide sufficient detail or sufficient area coverage, initiate action to collect additional materials. Start the analysis with materials on hand.

In this guide, source materials have been divided into three major categories: maps, literature, and aerial imagery.

C. Factor Overlay Preparation

1. Fasten a clean, translucent sheet of Mylar or other transparent material to a printed copy of the 1:50,000 scale map. If no 1:50,000 scale map is available, select an available map with a scale as near to 1:50,000 as possible. Where only very large or very small scale maps are available, the base map may have to be photographically enlarged or reduced to the desired scale. Place registration ticks on the overlay at each of the four map sheet corners. Although it is not essential, it may be helpful at later stages if the map sheet neatlines and 10,000 meter grid lines are traced lightly in pencil.

2. Add the map sheet name and number and other marginal information as required by Appendix A.

D. Data Table Preparation

Prepare blank work sheets for vegetation data tables 1 and 2 (Tables A1 and A2, Appendix A) on overlay material the same size as the factor overlay using the formats specified in Appendix A. Overlay material is required to facilitate diazo reproduction, but the material need not be the same stable base material required for the factor overlay.

E. Analysis Procedures

1. Vegetation Boundaries

a. Map Analysis

(1) The boundaries of vegetated areas are the most accurate and dependable vegetation information available on topographic maps and should be the starting point for all vegetation analysis wherever large-scale topographic maps ($>$ 1:75,000) are available.

(2) Where the source maps are at the same scale as the factor overlay (1:50,000), the overlay may be registered to the map and the boundaries traced directly. Where the source maps are at a different scale, the boundaries to the overlay must be transferred by one of the following methods:

(a) Have the source maps photographically enlarged or reduced to the overlay scale, and then trace the boundaries of vegetated areas, swamps, marshes, open water, and urban areas onto the overlay. This method requires access to a large copy-camera and a photographic laboratory, which may not always be practical.

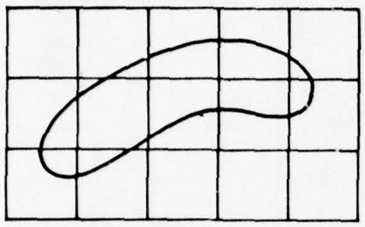
(b) Use a reflecting projector to project the source map onto the overlay at the same scale and then trace the boundaries. In tracing the boundaries, the map must be folded and worked on in small sections.

(c) Use a sketchmaster or Zoom Transferscope to transfer the boundaries. However, these instruments can accommodate only small sections of the map. In addition, they can be used only when the scale difference is small.

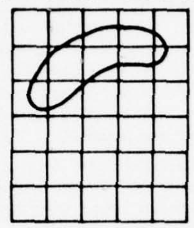
(d) Where available, a pantograph may be used.

(e) As a last resort, the boundaries may be transferred by using a system of squares similar to the following examples:

MAP SCALE 1:25,000
SIZE OF SQUARES 1cm



OVERLAY SCALE 1:50,000
SIZE OF SQUARES 0.5cm



This method of transferring detail is very slow and should be used only when revising or completing small areas on the overlay.

(3) When transferring boundaries to the overlay, care should be taken to insure that all vegetated areas are included and separate boundaries are provided for each type, i.e., woodlands, open areas, scrub, swamp, marsh, mangrove, etc. (Tables 3, 4 and 5)

(4) As the boundaries are drawn, make light erasable entries within each area to indicate the type of vegetation within the area, i.e. woodland, broadleaf, swamp, orchard, etc.

b. Literature Survey

(1) Review all available maps in data base, and transcribe appropriate data to overlay.

(2) Review all literature, reports, etc., and transcribe appropriate data to overlay.

c. Analysis of Photography

(1) Equipment and Materials

Stereoscope, folding pocket type.

Translucent data base overlay developed from map interpretation.

TABLE 3
INTERPRETATION OF VEGETATION
SYMBOLS ON US MAPS*

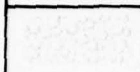
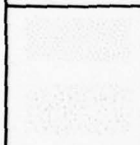
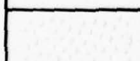
SYMBOL	LEGEND DESCRIPTION	GENERAL CHARACTERISTICS	CANOPY CLOSURE (%)	HEIGHT (METERS)	SEASONALITY
	Woodland	Woodland is a growth of perennial vegetation which includes various plant types: rainforest and/or moist evergreens, jungle (clear and dense), palm, palmetto, bamboo, orchards or plantations which are of irregular planting or wild growth, reforested areas, mesquite trees, and stunted trees (scrub-oak or scrub-pine) which comply with the woodland definition of density and height. Excluded from this category are scattered trees; isolated trees; tropical grass; mangrove; nipa; orchards, plantations and nurseries of systematically planted trees; and tall shrubs, cactus, thick low growths such as mesquite bush, sagebrush and dwarf trees (willow, birch, etc.) which are less than 10 feet (3m) high.	> 50	> 3	N.A.
	DECIDOUS (Proposed)		> 50	> 3	Estimate based on climate
	CONIFEROUS (Proposed)		> 50	> 3	N.A.
	MIXED (Proposed)		> 50	> 3	Estimate based on climate.
	Scrub	Scrub is a low, stunted vegetation such as cactus, mesquite bushes, sagebrush, dwarf trees (less than 10 feet (3m) in height), stunted shrubs, thickets, and other low plants which may present obstacles to free passage or may serve as landmarks in areas devoid of recognizable features. Scrub growth is not shown on medium scale assignments unless specified in supplemental project instructions.	> 50	< 3	Estimate based on climate.
	Scattered Trees	Can be either needleleaf or broadleaf.	25-50	> 3	N.A.
	DECIDOUS (Proposed)		25-50	> 3	Estimate based on climate.
	CONIFEROUS (Proposed)		25-50	> 3	N.A.
	MIXED (Proposed)		25-50	> 3	Estimate based on climate.

TABLE 3 (CONTINUED)
INTERPRETATION OF VEGETATION
SYMBOLS ON US MAPS

SYMBOL	LEGEND DESCRIPTION	GENERAL CHARACTERISTICS	CANOPY CLOSURE (%)	HEIGHT (METERS)	SEASONALITY
	Vineyard	Vineyards are areas covered by perennial vinelike growths. No distinction is made between types of vineyards, nor are they labeled. On medium scale maps, the vineyard symbolization is used to portray not only the supported vinelike growth, but also orchards, plantations, and nurseries.	N.A.	No	Estimate based on climate.
	Orchard or Plantation	An area of orchards or plantations usually consisting of rows of evenly spaced trees, common fruit orchards are not shown.	No	No	Estimate based on climate.
	Rows of Trees	Usually found along roads and fence rows.	N.A.	> 3	Estimate based on climate.
	Marsh or Swamp	Wet areas containing trees (swamp) or grasses (marsh).	No	No	Estimate based on climate.
	Coastal Marsh in Tidal Waters	The shoreline is drawn as the waterside limits of the marsh.	N.A.	< 3	N.A.
Peat bogs	Peat Bogs	The symbol is representative and does not show the actual shape or the number of cuttings.	N.A.	3	N.A.
Cranberry Bogs	Cranberry Bogs	Only major separations are shown. The inundation is controlled.	N.A.	< 3	N.A.
	Rice Paddy	Only fields subject to inundation, either controlled or natural, are shown. Minor ditches and levees are omitted.	N.A.	< 3	No
	Tropical Grass	Tropical grass is a dense growth of tall grass occurring in tropical or semi-tropical climates which affords concealment for and prevents rapid movement of troops. Low grass, not capable of providing concealment, is not shown.	N.A.	No	No change with season.
	Mangrove	Mangrove is a thick growth of trees with tangled aerial roots which appears in tropical and semi-tropical regions. It occurs in lowlying areas along seacoasts and along the banks of tidal waters up to the limits of the tidal influence. Where the exact location of the shoreline (mean high water) is not apparent, the water-side limit of the feature is annotated as the shoreline.	No	No	No change with season.

TABLE 3 (CONTINUED)
INTERPRETATION OF VEGETATION
SYMBOLS ON US MAPS

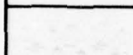
SYMBOL	LEGEND DESCRIPTION	GENERAL CHARACTERISTICS	CANOPY CLOSURE (%)	HEIGHT (METERS)	SEASONALITY
	Nipa Palm	Nipa is a dense growth of stemless palms found in tropical and semi-tropical tidal or brackish waters. It usually occurs farther inland than mangrove and generally forms strips in channels, through which tides ebb and flow. The feature is sometimes cultivated and systematically planted; such plantings are symbolized as nipa, not as an orchard. Where the exact location of the shoreline is not apparent, the waterside limit of the feature is annotated as the shoreline. The feature is delineated both as a drainage and a vegetation feature.	No	No	No change with season.
	Marshy Area in Northern Latitudes	This symbol represents features such as tundra in USSR and muskeg in Canada. The nature of the feature will be indicated in the legend.	N.A.	<3	Estimate based on climate.
	Coastal Marsh in Nontidal Water	The shoreline is drawn as the true shoreline.	N.A.	<3	Estimate based on climate.

TABLE 4
INTERPRETATION OF VEGETATION SYMBOLS
FEDERAL REPUBLIC OF GERMANY

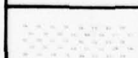
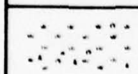
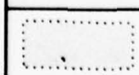
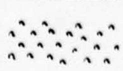
SYMBOL	LEGEND DESCRIPTION	GENERAL CHARACTERISTICS	CANOPY CLOSURE (%)	HEIGHT (METERS)	SEASONALITY
	Deciduous Forest (Laubwald)	Broadleaf tree species.	No	No	Estimate based on climate.
	Coniferous Forest (Nadelwald)	Needleleaf tree species.	No	No	Little seasonal change.
	Mixed Forest (Mischwald)	A mixture of broadleaf and needleleaf tree species.	No	No	No
	Heavily Cut-Over Forest (Kahischlag)	Timber has been harvested.	No	No	No
	Brushwood (Baume Und Gebusch)	Low shrub vegetation, can be either broadleaf or needleleaf.	No	No	No
	Park (Park)	Usually located in and surrounding small villages and towns.	No	No	No
	Vineyard (Weingarten)	Seasonal crop usually planted in rows. May reach 2 meters in height.	No	No	Estimate based on climate.
	Hop Field (Hupfen-anpflanzung)	Seasonal row crop reaching 3-4 meters in height.	No	No	Estimate based on climate.
	Pasture, Meadow (Weide, Wiese)	Vegetation is usually less than 1 meter in height.	N.A.	<1	Estimate based on climate.
	Heath (Heide)	All vegetation is usually less than 1 meter in height.	N.A.	<1	N.A.
	Marsh (Sumpf)	No distinction is made between fresh and salt marshes.	N.A.	No	Estimate based on climate.
	Nursery (Baumschule)	Small plants less than 2 meters in height.	N.A.	<2	No
	Garden (Garten)	Small cultivated areas located adjacent to towns and villages.	N.A.	N.A.	Estimate based on climate.
	Orchard (Obstbaumgut)	Trees usually over 2 meters in height. Canopy closure will change with seasons.	No	No	Estimate based on climate.
	Peat Cuttings (Torfstoch)	Area usually covered with low vegetation.	N.A.	N.A.	N.A.

TABLE 5
INTERPRETATION OF VEGETATION SYMBOLS ON RUSSIAN MAPS

SYMBOL	LEGEND DESCRIPTION	GENERAL CHARACTERISTICS	CANOPY CLOSURE (%)	HEIGHT (METERS)	SEASONALITY
клен $\frac{12}{0,25}$ 3	Deciduous Forest	Broadleaf trees that seasonally lose their leaves.	No	Yes	Estimate based on climate.
сосна $\frac{25}{0,30}$ 6	Coniferous Forest	Needleleaf trees, leaves remain on the tree throughout the year.	No	Yes	Little seasonal change.
ель бер $\frac{20}{0,25}$ 5	Mixed Forest	Mixed broadleaf, needleleaf forest.	No	Yes	No
$\frac{20}{0,30}$ 5 $\frac{25}{0,30}$ 6	Characteristics of Timber Stand in Meters	Numerator = Average height of trees. Denominator = Diameter. Number = Average tree spacing.	N.A.	N.A.	N.A.
клен $\frac{12}{0,25}$ 3	Species	Word adjacent to symbol indicates deciduous forest species composition. Oak (A), Beech (B), Maple (C), Birch (D), Aspen (E).	N.A.	N.A.	N.A.
сосна $\frac{25}{0,30}$ 6	Species	Word adjacent to symbol indicates coniferous forest species composition. Spruce (F), Fir (G), Pine (H), Cedar (I), Larch (J).	N.A.	N.A.	N.A.
2	Narrow Bands of Trees	Narrow bands of trees and protective trees. Number refers to average height of trees.	N.A.	Yes	No
	Small Forest Areas	These stands are not expressed at map scale.	No	No	No
1 2 3	Individual Woods	Not expressed at map scale (1) needleleaf, (2) broadleaf and (3) mixed.	No	No	Estimated from forest type.
1 2	Reference Trees	Single trees that may serve as reference points (1) needleleaf and (2) broadleaf.	N.A.	No	Estimated from forest type.
	Lone Trees	Trees marked in this manner have no significance as reference points.	N.A.	No	No
1 2 3	Palm Groves	1. Palm groves expressed at map scale. 2. Palm groves not expressed at map scale. 3. Single palm trees.	No	No	No change with season.

A. цуб, B. бук, C. клен, D. береза, E. осина

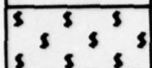
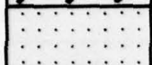
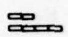
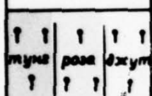
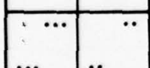
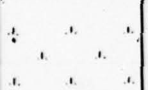
F. ель, G. пихта, H. сосна, I. кедр, J. лиственница

TABLE 5 (CONTINUED)
INTERPRETATION OF VEGETATION
SYMBOLS ON RUSSIAN MAPS

SYMBOL	LEGEND DESCRIPTION	GENERAL CHARACTERISTICS	CANOPY CLOSURE (%)	HEIGHT (METERS)	SEASONALITY
	Scrub Growth	Shrub and dwarf forest growth.	No	No	No
бер. 2	Forest Under-growth Nurseries Plantings	Vegetation indicated less than 4 meters in height. Number indicates average height of trees.	No	Yes	No
	Forest Blowdown	Trees uprooted by wind or high energy explosives.	N.A.	No	No
1 2	1. Sparse Woods 2. Sparse Scrub		No No	No No	No No
1 2	1.Burnt & Dry Forests 2. Felled Forests	Indicates areas of forest fire.	N.A.	No	No
22 23	Clearings	1:25,000 > 20 meters wide 1:50,000 > 40 meters wide 1:100,000 > 60 meters wide Number in or adjacent to clearings indicate width in meters. Bold face numbers (22,23) indicate number of forest blocks.	N.A.	N.A.	N.A.
1 2	Brush	1. Lone bushes and groups of bushes. 2. Continuous brush.	No	Yes	Estimate based on climate.
0.8 0.8 1 2	Brush Characteristics	1. Coniferous brush 0.8 meters high. 2. Deciduous brush 0.8 meters high.	No	Yes	Estimate based on climate.
	Narrow Strips of Brush and Living Fences	Found adjacent to roads and separating fields.	N.A.	o	No
	Continuous Thorny Brush	Growth usually not over 2 meters in height.	No	No	No
	Haloxylon*	1. Lone groups. 2. Continuous growth.	No	No	No
	Creeping Bushes	1. Lone groups. 2. Continuous growth.	No	No	No
	Bamboo Growth	Usually grows in large clumps, can reach 5-6 meters in height.	No	No	No change with season.

*Plants that tolerate high salt environments.

TABLE 5 (CONTINUED)
INTERPRETATION OF VEGETATION
SYMBOLS ON RUSSIAN MAPS

SYMBOL	LEGEND DESCRIPTION	GENERAL CHARACTERISTICS	CANOPY CLOSURE (%)	HEIGHT (METERS)	SEASONALITY
	Fruit and Citrus Gardens	Cultivated agricultural pattern.	N.A.	No	No
	Vineyards	Cultivated agricultural pattern.	N.A.	No	No
	Berry Gardens	Cultivated agricultural pattern.	N.A.	No	No
	Mangrove	Usually found along tropical coastlines.	No	No	No change with season.
	Hotbeds	Used for raising food and for starting plants (in cold areas). Shown on 1:25,000 maps only.	N.A.	No	N.A.
	Rice Fields	1. Dry. 2. Water covered.	No No	No No	No No
	Plantations of Technical Crops	1. Woody plants. 2. Non-woody plants. 3. Grass crops.	No	No	No
	Meadow	1. Grass < 1 meter in height. 2. Grass > 1 meter in height.	N.A.	Yes	No
	Reed and Cane Growth	Agricultural land use pattern.	No	No	No
	Wet Meadows	1. Permanently wet land. 2. Reed and cane covered.	N.A.	No	No
	Steppe	1. Grassy vegetation. 2. Under shrub.	N.A.	No	
	Moss and Lichen	Usually found on terrain at high altitudes and latitudes.	N.A.	No	Little seasonal change.
	Swamps	Impassable swamps and swamps difficult to negotiate (1.8 meters deep).	No	No	No
	Swamps	Passable swamps (0.6 meters deep).	No	No	No
	Swamps Vegetation	1. Grassy. 2. Mossy. 3. Reed and cane.	No	No	No

Wax base red pencil, felt tip pen, or "Prisma Color" pencil.

Stapler.

Masking tape.

Vertical aerial photographic prints of area of interest with approximately 60 percent overlap along the flight line and 30 percent between flight lines.*

4- by 8-foot soft fiber board for mosaicking aerial photography.

Clear acetate or mylar.

Good quality hand lens.

Paper cutter.

Erasers.

Writing pads.

Rulers.

Ink solvent.

(2) Procedure

(a) Mosaic aerial photography on a 4- by 8-foot soft fiber board. During analysis, this board can be placed on a layout table or on a pair of sawhorses with a supporting sheet of plywood.

1. Separate the photos of each strip (flight line) into two stacks by pulling out alternate prints; photos 1, 3, 5, 7, etc. from one group, and photos 2, 4, 6, 8, etc. from the second group. One group of photographs forms the mosaic; the other is used later in the analysis when stereo viewing is required.

2. Sequentially, lay out and overlap (approximately 10%) alternate photographs of the flight line that most closely bisect the center of the area of interest (either group of photographs may be used).

3. Mosaic these photographs together, maintaining as closely as possible the geometric integrity of visible landscape features, i.e., align streams, roads, ridge lines, etc. (do not fasten the photographs with staples at this time).

*Photographic scale should be equal to or larger than 1:20,000.

4. After mosaicking the central flight line, continue with the flight line on either side of the central one and again lay out every other photograph. It may be necessary to realign previously mosaicked photographs in order to best align linear features.

5. Repeat the above procedure for each flight line. Continually re-adjust photographs to attain best fit.

6. When each flight line is mosaicked to your satisfaction, stapel photograph corners to maintain alignment (see Figure 9).

7. Cut a piece of clear acetate or mylar of sufficient size to cover the mosaicked photography.

(b) Outline with felt tip pen or wax base pencil the boundaries of each major land use category, e.g., water, urban areas, and agricultural areas. In addition, naturally vegetated areas (including managed forest stands) should be outlined and, where possible, divided into ground cover (less than 2m in height) and forest (2 m or greater in height). Identify each area outlined on the overlay with a single letter designation, e.g., w = water and u = urban areas. These land use designations are for your own use and are not transferred to the factor overlay.

NOTE: It is generally best to classify the entire mosaicked area before proceeding further in the analysis.

(c) Sequentially examine each mosaicked photograph by orienting the adjacent photograph in the flight line in stereo. Once stereo vision has been established, remember to securely fasten the photograph with masking tape. Stereoscopically differentiate and outline the vegetated areas that appear taller than 2 meters into three basic vegetation types as shown below:

FOREST TYPE	DESIGNATION	COMPOSITION
Needleleaf	N	60% or greater needleleaf cover
Broadleaf	B	60% or greater broadleaf cover
Mixed	NB	Greater than 40% broadleaf & less than 60% needleleaf cover
	BN	Greater than 40% needleleaf & less than 60% broadleaf cover

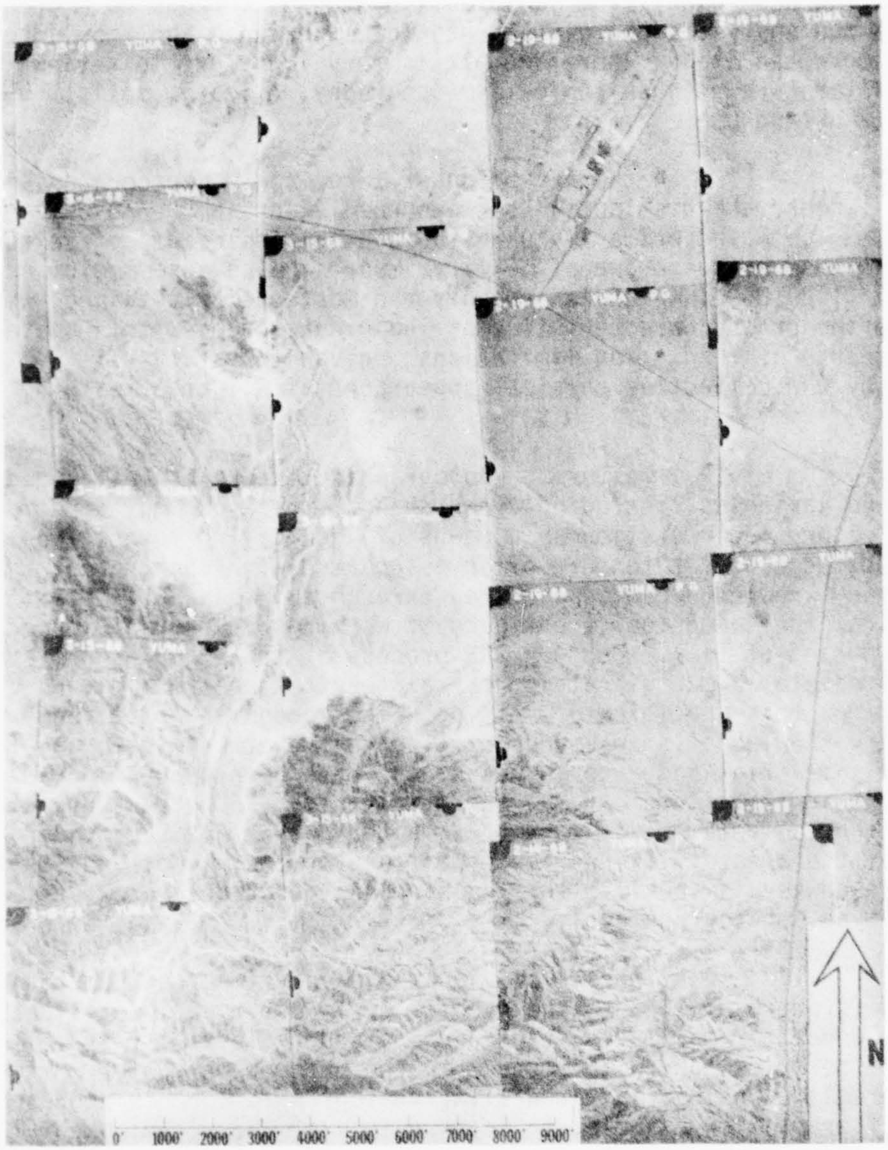


FIGURE 9. Photo Mosaic.

The degree to which the analyst is successful in differentiating needleleaf from broadleaf vegetation depends to a great extent upon the analyst's photointerpretation experience and knowledge of the photographed area. Therefore, it is very important to review available literature on such topics as topography, climate, soils, vegetation, and land use.

With the exception of large scale photography, i.e. 1:5,000 or larger, the distinction between needleleaf and broadleaf vegetation will be based primarily upon the pictorial elements of texture and tone.* These elements are of primary importance because medium scale photography (1:20,000), which is probably the most easily obtained, will not resolve the crown characteristics of individual trees within a stand. Instead, because of resolution limitations, a given forest type is identified by the collective physical appearance of all trees within the stand.

1. Texture. Photographic texture is influenced by several stand variables, including crown shapes, tree spacing, and tree heights. Texture interpetation as a means of identifying forest type requires knowledge of the texture often associated with each forest type. This necessary knowledge can be acquired through two means. The first means requires the "hands on" experience of working with aerial imagery for a long period of time. Through the process of trial and error, an analyst can develop a mental catalog to relate a texture in a given geographic area to a specific forest type. The second means of acquiring the necessary knowledge is to use vegetation keys that have been developed through the same trial-and-error process, but have been documented and are available in the literature.** Vegetation keys can be very useful in certain instances; however, it must be remembered that (1) background knowledge of the area of interest is essential for their use, and (2) in most instances, each key is specific to tree species, geographic area, time of year, film type, photograph scale, etc.

2. Tone. Tone is also a very important pictorial element and is often applied to the problem of forest type identification. Tone is influenced primarily by stand density and reflectivity as well as location of the tree stand with respect to the photograph center. When using panchromatic and B&W infrared film, photographic tone is represented by shades of gray. For example, in most regions of the world, needleleaf trees will image darker in tone than broadleaf trees on panchromatic film given equivalent stand density. This tone differentiation is due to higher reflectivity of broadleaf trees in the region of the electromagnetic spectrum (0.3 - 0.7μm) to which the film is sensitive (see Figures 10-11).

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*When using aerial photography of 1:5,000 or larger, individual crown characteristics, e.g. shape and type of branching, become more important because of greater resolution.

**Many of the keys available for vegetation of the world are listed under species identification in Appendix B.

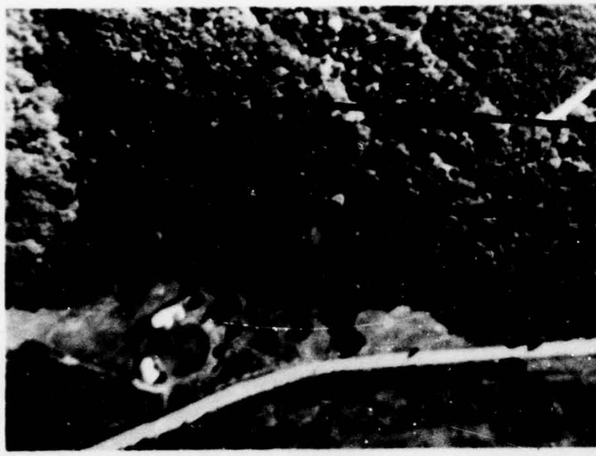

Figure 10. **B&W AERIAL PHOTO**

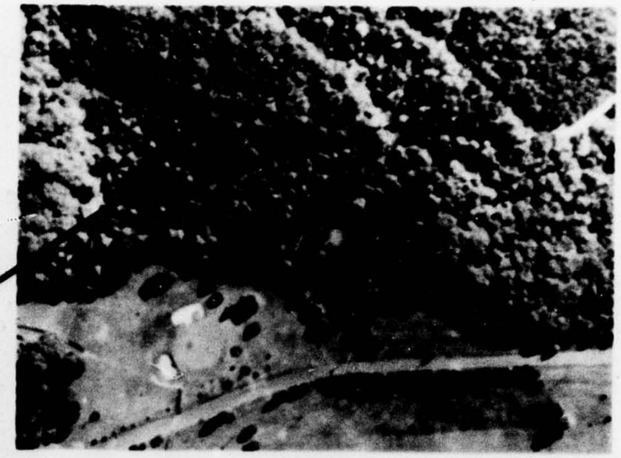

Figure 11. **B&W IR AERIAL PHOTO**

Figure 12. **COLOR AERIAL PHOTO**

Figure 13. **COLOR IR AERIAL PHOTO**

When using color and color infrared film, tone is often referred to as hue and is represented as shades of the color imaged. For example, in most instances broadleaf trees appear light green in hue on color film, whereas needleleaf trees appear dark green. This differentiation in hue is due to the higher reflectivity of broadleaf trees in the green region of the electromagnetic spectrum (see Figures 12-13).

(d) Stereoscopically stratify the three basic forest types, i.e. needleleaf (N), broadleaf (B), and mixed (NB, BN) into 2 meter increment height classes, and outline each area on the clear acetate overlay. At the same time, estimate mean canopy height in meters for each homogeneous area, and record this value within the boundaries of the area.* At this point, the analyst may find that the original stratification boundaries based upon height were not optimal. Boundaries must be redrawn to best reflect height homogeneity within each forest type. Upon completion of the redrawing of map unit boundaries, determine each unit's average canopy closure using procedures described under Percent Canopy Closure by Season, paragraph 3.

(e) Identify each map unit on the clear acetate overlay with the appropriate forest type letter designation, i.e. N, B, NB, or BN. Assign identification numbers to each vegetation unit, starting in the upper left hand corner of the overlay and proceeding downward in a normal reading manner. The map units with the same vegetation type, canopy closure, and height are assigned the same identification number (Figure 14).

2. Mean Height to Top of Canopy. This data element is defined as the mean, or average, height of the trees within each map unit (Figure 15).

a. Map Analysis. Approximate canopy height can be obtained for each vegetation map unit located on a U.S. Standard Military Topographic Map by examination of the map legend (Table 4). Maps produced by the U.S.S.R. contain this data for each vegetation unit. This data should be recorded in pencil within each area of the overlay.

*Canopy height measurement procedures are presented under Mean Height to Top of Canopy, paragraph 2.

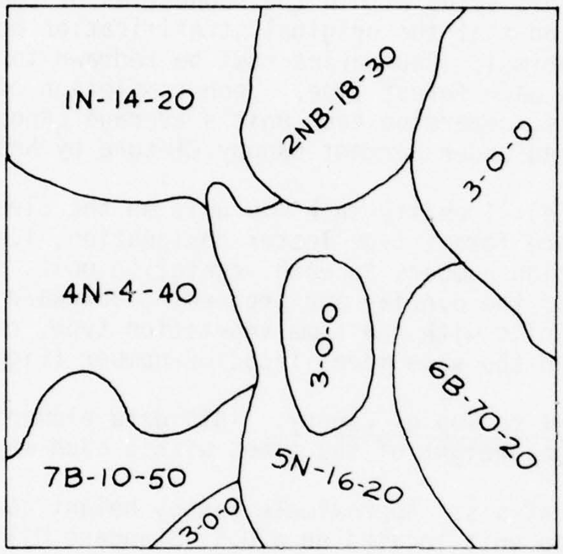

FIGURE 14. Portion of a Factor Overlay.

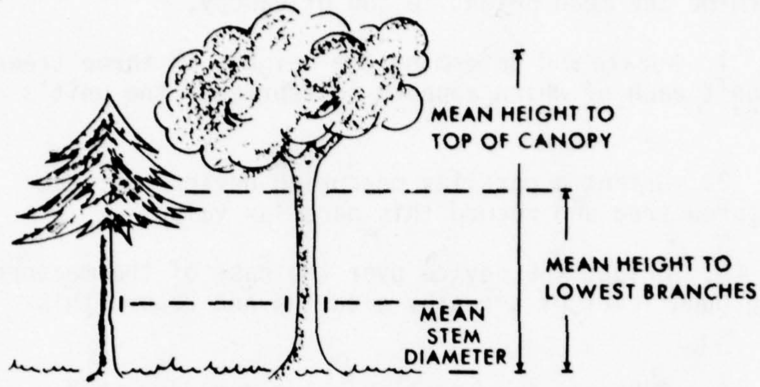

FIGURE 15. Mean Height to Top of Canopy.

b. Literature Survey.

(1) Review all available maps in data base and transcribe appropriate data to overlay.

(2) Review all literature, reports, etc. and transcribe appropriate data to overlay.

c. Analysis of Photography.

(1) Equipment and Materials.

Stereoscope, folding pocket type.

Parallax measuring device (parallax wedge or parallax bar).

Masking tape.

Vertical aerial photographic prints of area of interest with approximately 60% overlap along the flight line and 30% between flight lines.*

Vegetation Data Table I.

(2) Procedure.

(a) Orient stereopair for viewing. Securely fasten stereo mate (alternate) photo to clear acetate overlaying the photo mosaic.

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*Photographic scale should be equal to or larger than 1:20,000.

(b) For each map unit containing vegetation 2 m or greater in height, determine the mean height to top of canopy.

1. Locate and determine the heights of three trees within the map unit each of which appears to represent the unit's average height.

2. Orient a parallax measuring device over the apex of the measured tree and record this parallax value.

3. Orient the device over the base of the measured tree or at the ground level of a nearby clearing and record this parallax value.

4. Subtract the parallax value recorded at 2. from that recorded at 3. to determine the parallax difference (Dp).

For example: Dp = 2. - 3.

Dp = 0.236 ft - 0.233 ft

Dp = 0.003 ft

NOTE: To reduce variability caused by single measurements, several measurements of parallax difference should be made and the results averaged.

5. Insert parallax difference (Dp) into the height formula and calculate tree's height.

Dh = height of tree

Dp = parallax difference

H-h = vertical distance between camera and base of tree

Bm = mean photographic base

$$Dh = \frac{(H-h)\ (Dp)}{Bm + Dp}$$

Dp = 0.003 ft

H = 8000 ft

h = 200 ft

Bm = 0.355 ft

$$Dh = \frac{(8000 - 200)(0.003)}{0.355 + 0.003}$$

$$= \frac{(7800)(0.003)}{0.358} = \frac{23.4}{0.358}$$

$$= 65.4 \text{ ft}$$

NOTE: If ground level at the base of the tree differs from the elevation of the principal points by more than 200 or 300 ft, absolute stereoscopic parallax should be substituted for mean photographic base.[2]

6. Convert the calculated tree height to meters.

Example: tree height = 65.4 ft

1 m = 3.3 ft

$$\text{tree height (m)} = \frac{65.4 \text{ ft}}{1} \times \frac{1 \text{ m}}{3.3 \text{ ft}}$$

$$= 19.8 \text{ meters}$$

(c) Determine the mean of the three photo-measured tree heights and record this value to the nearest meter in Vegetation Data Table 1 (Appendix A, Table A1) as well as within the appropriate factor overlay map unit.

(3) Factors Affecting Accuracy of Height Measurements

(a) Photographic scale - Tree-height measurement error generally increases when small-scale photography is used owing to inability of the analyst to discern the tree's apex, e.g. objects having a diameter of less than 4 ft will not be resolved on 1:16,000 scale photography. For this reason, height measurements are normally underestimated and can be compensated for by making arbitrary corrections as shown in Table 6.

[2] T. E. Avery, Interpretation of Aerial Photographs, 2nd Edition, Burgess Publishing Co., Minneapolis, MN, 1968.

TABLE 6. Corrections in Tree Height to Compensate for Lack of Resolution

Scale of Photographs	Tapering Crowns	Normal Crowns	Broad Crowns
	Arbitrary correction in feet		
1:10,000	2	1	0
1:16,000	3.5	2	0.5
1:20,000	5	3	1

SOURCE: S. H. Spurr, Photogrammetry and Photo-Interpretation, New York, Ronald Press Co., 1960.

(b) Character of Forest - Measurement of tree heights is dependent upon the analyst's ability to see the ground nearby. This, of course, is closely allied with stand density and ground closure. If a forest stand is very dense, e.g. tropical forest, it is very difficult to find an opening large enough to permit the analyst to take a parallax reading. In this case the analyst must attempt to find a nearby opening at a height equivalent to that at the base of the tree.

(c) Terrain Relief - Trees growing in areas that are not level are more difficult to measure accurately owing to the tendency to refer measurements to canopy openings at an elevation different from that at the base of the tree. The heights of trees growing in valleys and depressions are frequently underestimated and those of trees growing on knolls or rises are usually overestimated.

(d) Analyst Skill - An analyst of average skill should be able to determine the height of trees accurately within each map unit in accordance with the height ranges shown in Table 7 below.

TABLE 7. TREE HEIGHT ACCURACIES OF THREE PHOTOGRAPHIC SCALES

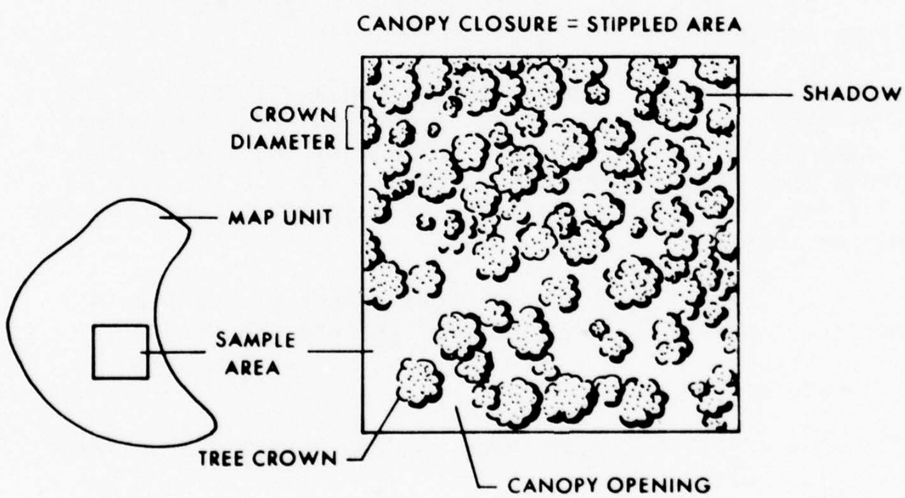
Photographic Scale	Height Range (ft)	(m)
1:20,000	20	6
1:15,840	10	3
1:1[illegible],000	5	2

SOURCE: S. H. Spurr, Photogrammetry and Photo-Interpretation, New York, Ronald Press Co., 1960.

Knowledge of forest conditions can be an invaluable aid in the height classification of a forest stand. For instance, the analyst, either because of prior experience or through collateral information, ascertains that broadleaf trees in a certain locality will seldom grow higher than 80 feet. This arbitrary limit can be assigned to the tallest broadleaf trees in the photographic sample, which then serves as a standard for comparision with other trees in the stand.

3. Percent Canopy Closure by Season. Canopy closure is defined as the proportion of each map unit's ground surface covered by tree crowns. This proportion is expressed as a percentage (Figure 16). In temperate broadleaf forests, percent canopy closure reaches its maximum value during the spring and summer months and decreases to its lowest value during the fall and winter months.

FIGURE 16. Canopy Closure



a. Map Analysis

(1) U.S. - Limited information concerning percent canopy closure is available in that areas classified as woodland have 50 percent or more crown cover. Areas defined as scattered trees have approximately 25 to 50 percent crown cover (Table 3). Information necessary to determine canopy closure seasonality is not available.

(2) F.R.G. - Information necessary to determine percent canopy closure by season is not available.

(3) U.S.S.R. - Percent canopy closure, although not given on U.S.S.R. topographic maps, can be estimated from stand parameters that are given, i.e. average tree height, diameter, and spacing (Table 5). Information necessary to determine canopy closure seasonality is not available.

(4) Although the seasonality of the canopy closure cannot be determined directly from topographic maps, certain inferences can be made.

(a) Stands that are predominantly needleleaf will maintain the same canopy closure throughout the year.

(b) Broadleaf canopy closure can be estimated if the average dates of the first and last frosts are known. Most broadleaf species have attained 50 percent of their foliage by the time of the last spring frost and retain 75 percent of the foliage at the time of the first fall frost. Complete defoliation has usually occurred by the time of the winter solstice.

(c) Defoliation of deciduous broadleaf species in tropical areas occurs during the last half of the dry season.

b. Literature Survey

(1) Review all available maps in data base and transcribe appropriate data to overlay.

(2) Review all literature, reports, etc. and transcribe appropriate data to overlay.

c. Analysis of Photography

(1) Equipment and Materials.

Stereoscope, folding pocket type.

Crown closure measuring device (crown density scale or stereogram of stands having known crown closure.

Vertical aerial photographic prints of area of interest with approximately 60 percent overlap along the flight line and 30 percent between flight lines.*

Vegetation Data Table I.

Masking tape.

(2) Procedure

(a) Orient stereo pair for viewing. Securely fasten stereo mate (alternate photo) to clear acetate overlaying the photo mosaic.

(b) Determine canopy closure to nearest 10 percent for each previously outlined homogeneous area/map unit located on the photo.

1. Crown density scale

a. Place density scale next to the homogeneous area, and slide up or down until the densities of the photo and scale correspond (see Figure 17).

b. If the canopy closure value represents the season of maximum canopy density, e.g. summer in temperate climates, record this value on the factor overlay in the appropriate homogeneous area. If the canopy closure value represents the forest in other than the fully *leafed conditions, e.g. early spring or late fall, record this value in* the appropriate column of Vegetation Data Table 1.

2. Stereogram

a. Place the stereogram of stands having known crown closure beside a homogeneous area of unknown density. Compare the known densities with the unknown density until a match is found.

b. Record the canopy closure value as indicated in (1.b.) above.

(3) Factors Affecting Accuracy of Crown Closure Measurement

(a) Image quality - Crown closure estimates of forest stands on poor quality, e.g. fuzzy, extremely dark or light, photography tend to be too high because of the absence of detail in tone extremes and inability of the analyst to discern small canopy openings.

*Photographic scale should be equal to or larger than 1:20,000.

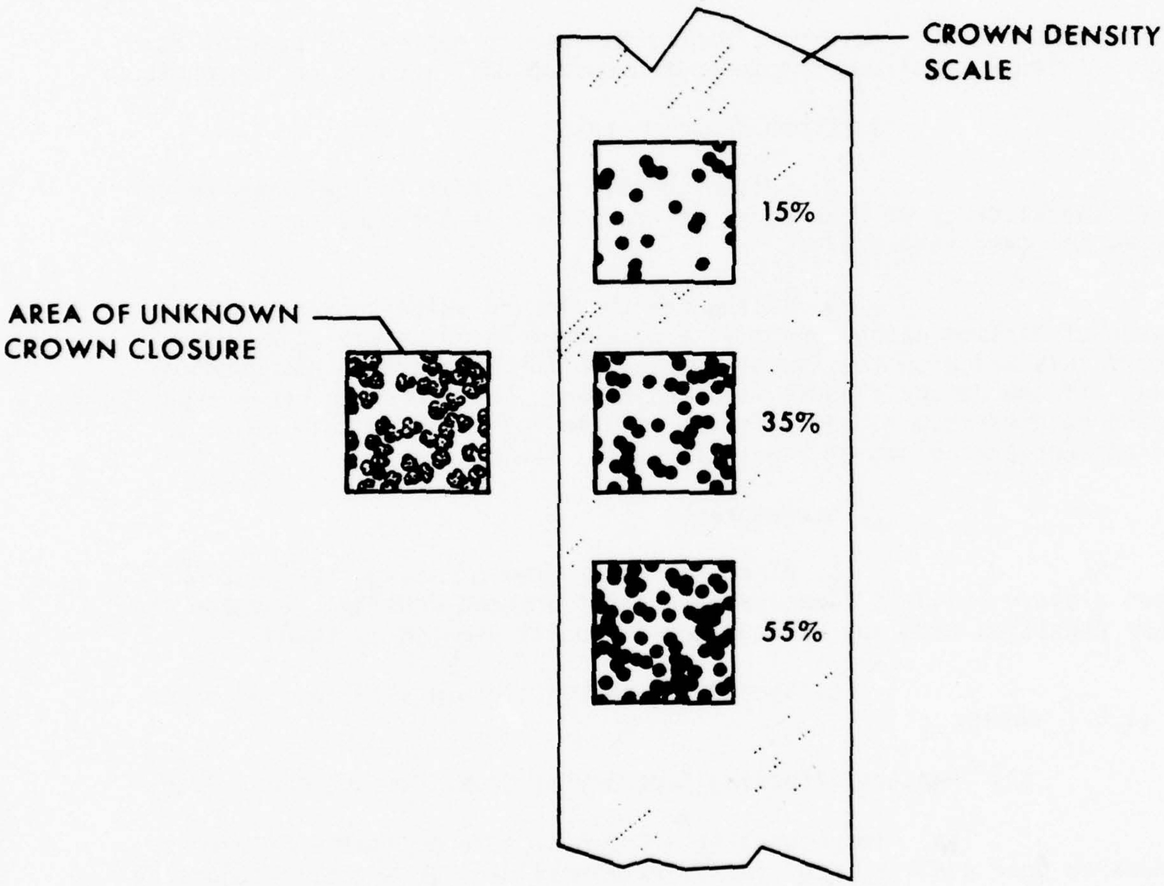


FIGURE   Placement of Crown Density Scale

(b) Shadows - The estimate of crown closure is affected by shadows because of their tendency to mask stand openings and thereby cause the stand to appear more dense than it actually is.

(c) Photographic scale - The minimum canopy opening size that will be resolved on aerial photography is directly related to photographic scale. Small openings can be discerned on 1:6,000 scale photography with only the largest canopy openings able to be seen on 1:20,000 scale photography. The net effect is to overestimate canopy closure when using relatively small scale photography.

(d) Analyst skill - An average analyst using good quality photographs of not less than 1:20,000 scale should produce crown closure estimates accurate to within 10 percent.[3]

4. Map Unit Identification

a. At this point, review the mosaic overlay and the factor overlay, and resolve any differences.

b. Assign each map unit area an identification number and record the number on the factor overlay and in Data Tables 1 and 2.

c. Categorize the vegetated areas over 2 meters high as needleleaf (N), broadleaf (B), or mixed (NB or BN). Areas with no vegetation or vegetation less than 2 meters high are not classified. Record the symbol on the factor overlay immediately to the right of the identification number, i.e. 2N, 3B, 4NB, 5BN.

d. Determine the mean height to the top of the canopy in meters, and record it to the right of the ID number and vegetation type on the factor overlay and in Data Table 1.

e. Record the maximum percent canopy closure to the right of the height class symbol (Figure 18).

f. Record the seasonal canopy closures for each map unit area in Data Table 1.

---

[3] S. H. Spurr, Aerial Photographs in Forestry, The Ronald Press Company, New York, 1948.

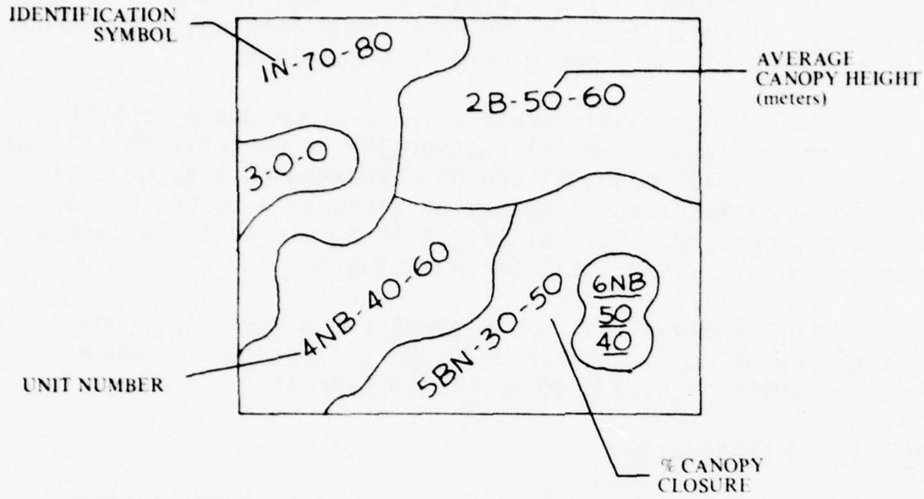


FIGURE 18. Map Unit Identification/ Vegetation Boundaries

5. Number of Stems per Hectare. This data element provides for each map unit a count of the number of trees 2 meters or greater in height per representative hectare.

a. Map Analysis. This data element cannot be obtained from standard military topographic maps. Aerial photography or other data sources will have to be employed.

b. Literature Survey.

(1) Review all available maps in data base and transcribe appropriate data to overlay.

(2) Review all literature, reports, etc. and transcribe appropriate data to overlay.

c. Analysis of Photography.

(1) Equipment and Materials.

Stereoscope, folding pocket type.

Transparent template with scribed circles approximating 0.08 hectare (1/5 acre) at various photographic scales.*

Masking tape.

Needles for point pricking.

Light table.

Drop compass set.

Vertical aerial photographic prints of area of interest with approximately 60 percent overlap along the flight line and 30 percent between flight lines.**

Vegetation Data Table 1 (Appendix A, Table A1).

(2) Procedure

(a) Calculate representative fraction (RF) of the photography by one of the following methods:

<u>Focal Length/Altitude Method</u>

$$RF = \frac{f}{H-h}$$

f = focal length of camera
H = altitude of aircraft
h = mean elevation of area covered by photograph

<u>Photo Distance/Ground Distance</u>

$$RF = \frac{Pd}{Gd}$$

Pd = photo distance
Gd = ground distance

<u>Photo Distance/Map Distance</u>

$$RF = \frac{Pd}{Md} \times MRF$$

Pd = photo distance
Md = map distance
MRF = RF of map

---

*Preparation of this or similar transparencies can be accomplished by drawing the circles in ink on white paper at several times the required radius, reducing the figure photographically, and then preparing positive film transparencies.

A 0.08 hectare sample is probably the most commonly used sample size; however, it may be 0.10 hectare, 0.20 hectare, 1 hectare (2.471 acres), etc. depending primarily upon stand density and homogeneity.

**Photographic scale should be equal to or larger than 1:20,000.

Example: $f = 6"$ (.5 ft.)

$H = 5000$ ft.

$h = 1000$ ft.

$$RF = \frac{f}{H-h}$$

$$= \frac{0.5}{(5,000)-(1,000)}$$

$$= \frac{0.5}{4,000}$$

$$= 1:8,000$$

(b) Select a circle of the appropriate size from Table 8 or calculate radius of a circle needed to enclose 0.08 hectare at scale of photography (use of 0.08 hectare as a sample size is not a hard and fast rule).[4]

Example: focal length of camera = 12 inches

altitude of aircraft = 10,000 ft.

representative fraction = 1:10,000

1. Calculate radius of 0.08 hectare field plot.

$a = \pi r^2$ — Number of square meters in 1 hectare = 10,000

$r = \sqrt{\frac{a}{\pi}}$ — Number of square meters in 0.08 hectare = 800

$$r = \sqrt{\frac{800}{3.14}}$$

$r = 15.96$ m (radius of 0.08 hectare field plot)

---

[4] S. H. Spurr, Photogrammetry and Photo-Interpretation, 2nd Edition, The Ronald Press Company, New York, 1960.

2. Calculate the number of meters per millimeter at scale of photography.

Representative fraction = 1:10,000

$$1 \text{ mm} = \frac{10,000 \text{ mm}}{1,000}$$

$$1 \text{ mm} = 10 \text{ m}$$

3. Calculate photo measured radius of 0.08 hectare.

$$\text{Radius of 0.08 hectare as measured on the photograph} = \frac{\text{radius of 0.08 hectare (m)}}{\text{photographic scale (m/mm)}}$$

$$= \frac{15.96\text{m}}{10\text{m/mm}} = \frac{15.96\text{m}}{1} \times \frac{1\text{mm}}{10\text{m}}$$

$$= 1.6 \text{ mm}$$

For an elevation on the ground 500 ft. lower, or 10,500 ft. below the aircraft, similar calculations would be employed.

Example: representative fraction = 1:10,500

$$1\text{mm} = \frac{10,500\text{mm}}{1000}$$

$$1\text{mm} = 10.5\text{m}$$

$$\text{Radius of 0.08 hectare as measured on the photograph} = \frac{15.96\text{m}}{10.5\text{m/mm}} = \frac{15.96\text{m}}{1} \times \frac{1\text{mm}}{10.5\text{m}}$$

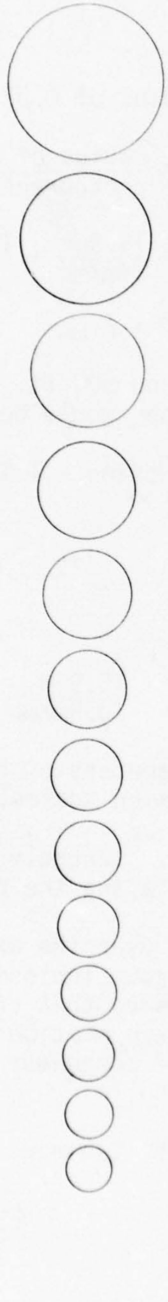
Table 8 gives the inside diameters of circular sample plots covering various ground areas at different common scales.

(c) Orient stereo pair for viewing. Securely fasten stereo mate (alternate photo) to clear acetate overlaying the photo mosaic.

(d) Place the transparent template over the area of interest, and count the number of trees by pinpricking each crown inclosed by the 0.08 hectare circle* (See Figure 19). It must be remembered that crown counts taken from aerial photography are usually low and care must be taken to segregate clumps of trees into the correct number of component trees.

*If desired, this process may be performed on a light table.

TABLE 8
CIRCLE DIAMETERS
1 HECTARE AREA
(10,000 square meters)

PHOTO SCALE	1 HECTARE CIRCLE	CIRCLE DIAMETER INCHES	CIRCLE DIAMETER MILLIMETERS
1:5,000		.888	22.57
1:6,000		.740	18.81
1:7,000		.634	16.12
1:8,000		.555	14.10
1:9,000		.493	12.54
1:10,000		.444	11.28
1:11,000		.404	10.26
1:12,000		.370	9.40
1:13,000		.342	8.68
1:14,000		.317	8.06
1:15,000		.296	7.52
1:16,000		.278	7.05
1:17,000		.261	6.64

1:18,000	.247	6.27
1:19,000	.234	5.94
1:20,000	.222	5.64
1:21,000	.211	5.37
1:22,000	.202	5.13
1:23,000	.193	4.91
1:24,000	.185	4.70
1:25,000	.178	4.51

TABLE 8 Cont.
CIRCLE DIAMETERS
1/2 HECTARE AREA
(5,000 square meters)

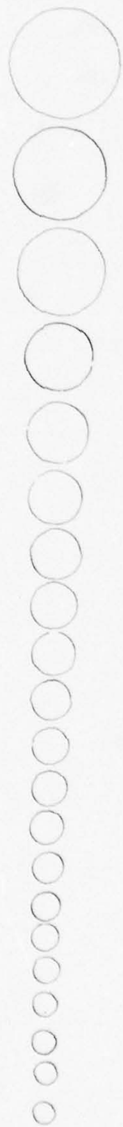
PHOTO SCALE	1/2 HECTARE CIRCLE	CIRCLE DIAMETER INCHES	CIRCLE DIAMETER MILLIMETERS
1:5,000		.628	15.96
1:6,000		.523	13.30
1:7,000		.449	11.40
1:8,000		.393	9.98
1:9,000		.349	8.87
1:10,000		.314	7.98
1:11,000		.285	7.25
1:12,000		.262	6.65
1:13,000		.242	6.14
1:14,000		.224	5.70
1:15,000		.209	5.32
1:16,000		.196	4.99
1:17,000		.185	4.70
1:18,000		.174	4.43
1:19,000		.165	4.20
1:20,000		.157	3.99
1:21,000		.150	3.80
1:22,000		.143	3.63
1:23,000		.137	3.47
1:24,000		.131	3.32
1:25,000		.126	3.19

TABLE 8 Cont.
CIRCLE DIAMETERS
.08 HECTARE AREA, (1/5 ACRE)
(800 Square Meters, 8712 Square Feet)

PHOTO SCALE	.08 HECTARE CIRCLE	CIRCLE DIAMETER INCHES	CIRCLE DIAMETER MILLIMETERS
1:5,000		.253	6.38
1:6,000		.211	5.32
1:7,000		.1805	4.56
1:8,000		.158	3.99
1:9,000		.140	3.55
1:10,000		.126	3.192
1:11,000		.115	2.90
1:12,000		.105	2.66
1:13,000		.092	2.46
1:14,000		.090	2.28
1:15,000		.084	2.13
1:16,000		.079	1.99
1:17,000		.074	1.88
1:18,000		.070	1.77
1:19,000		.067	1.68
1:20,000		.063	1.60
1:21,000		.060	1.52
1:22,000		.057	1.45
1:23,000		.055	1.39
1:24,000		.053	1.33
1:25,000		.051	1.28

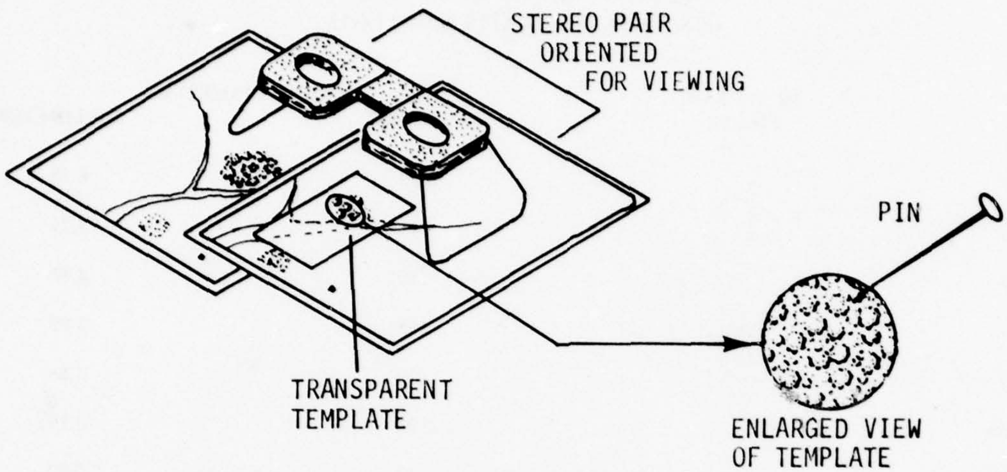


FIGURE 19. Orientation of Folding Pocket Stereoscope and Transparent Template

Convert the number of trees in 0.08 hectare to the number of trees per hectare.

Example: 25 trees counted within the 0.08 hectare scribed circle

$$\text{Number of trees per hectare} = \frac{25 \text{ trees}}{0.08 \text{ hectare}} = 313$$

(e) Record the number of stems per hectare in Vegetation Data Table 1.

(3) Alternate Methods

(a) When crown count corrections owing to elevation are needed infrequently, a single radius circle may be used and corrections made mathematically.[5]

[5] A. A. Grumbine, Forest Interpretation of Aerial Photographs, U. S. Forest Service, Washington, DC, 1946.

Example: If 32 trees are counted in a 0.08 hectare circle constructed for 1:12,000 photograph, but the stand is at an elevation where the scale is 1:12,500, the number of trees per hectare is calculated as follows:

$$\text{Number of trees per hectare} = \frac{\text{No. of trees counted at altered datum plane}}{(0.08)\left(\frac{\text{scale at altered datum plane}}{\text{nominal scale}}\right)^2}$$

$$= \frac{32}{(0.08)\ \left(\frac{12,500}{12,000}\right)^2}$$

$$= 369$$

(b) Smith (1965) while working with commercial tree species in British Columbia devised a formula for calculation of number of trees per hectare. He assumed that the average tree had a crown which occupied a circle with a diameter equal to the average crown width (CD) and that crown closure (CC) represented the proportion of the average hectare that is covered with trees.

$$\text{Number of trees per hectare} = \frac{10,000}{0.7854\ CD^2} \times CC$$

Example: $$\text{No. of trees per hectare} = \frac{10,000}{(0.7854)(3m)^2} \times 0.75 = 1061$$

(4) Factors Affecting Tree Count Accuracy

(a) Tree spacing - only those trees which are visible from above and are sufficiently large in their exposed portion to be resolved will be counted. This problem is especially acute in tropical areas having more than one canopy.

(b) Photography scale - trees having a crown diameter of less than 0.6m will not be resolved at 1:12,000 scale photography. This minimum resolved diameter increases to 1.2m on photos of 1:16,000 scale or smaller.[6]

(c) Tree crown diameter - tree count accuracy increases with an increase in tree crown diameter

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[6] M. J. Ferree, A Method of Estimating Timber Volumes from Aerial Photographs, College of Forestry, Syracuse State Univ. Technical Publication 75, 1953.

(d) Crown canopy structure - irregularities in crown canopy tend to increase accuracy owing to relief among trees.

(e) Terrain - if the terrain imaged in the photograph is not level, the area represented by a given scribed circle varies from one elevation to another. To compensate for terrain undulations, the radius of the scribed circle must be altered or the crown count adjusted to obtain the true number of stems per hectare. Compensation for terrain relief should be computed for about every 200-foot difference in elevation.[7]

(f) Analyst skill - inexperienced analysts may undercount the actual number of tree crowns by as much as 50 percent. For this reason, care must be exercised to recognize double trees, sprout clumps, or other multiple groups of trees. Detection of these groups is usually accomplished by recognition of abnormally large crowns or by the irregular shape of groups of crowns.[8]

(5) Record the mean number of stems in column 2 of Vegetation Data Table 1 (Table A1).

6. Tree Crown Diameter. Crown diameter is defined as the distance across the spread of a tree crown measured in meters (Figure 20). Diameter measurements of the largest, average, and smallest crowns in the primary canopy characterize each map unit. These measurements, made by crown micrometer wedge or dot type scale, are utilized to determine each map unit's stem diameter size distribution.

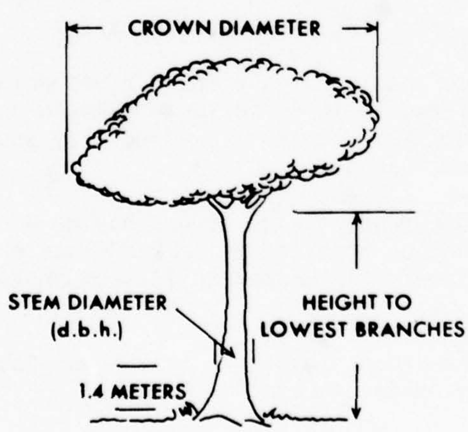

FIGURE 20. Tree Mensuration.

[7] M. J. Ferree, A Method of Estimating Timber Volumes from Aerial Photographs, College of Forestry, Syracuse State Univ., Technical Publication 75. 1953.

[8] Ibid

a. Map Analysis. This data element cannot be obtained from standard military topographic maps. Aerial photography or other data sources will have to be employed.

b. Literature Survey.

(1) Review all available maps in data base and transcribe appropriate data to overlay.

(2) Review all literature, reports, etc., and transcribe appropriate data to overlay.

c. Analysis of Photography.

(1) Equipment and Materials.

Stereoscope, folding pocket type.

Crown measuring device (crown micrometer wedge or dot type scale).

Masking tape.

Vertical aerial photographic prints of area of interest with approximately 60 percent overlap along the flight line and 30 percent between flight lines.*

(2) Procedure.

(a) Calculate the representative fraction of the photography. For methodology see page 60.

(b) Orient stereo pair for viewing. Securely fasten stereo mate (alternate photo) to clear acetate overlaying the photo mosaic.

(c) Compare the visible tree crown diameters in the primary canopy of each map unit. Locate three crowns, which correspond to the largest, average, and smallest crowns respectively.

(d) Determine the crown diameter of each of the selected trees.

1. Crown Micrometer Wedge

a. Select a tree for measurement and place the wedge so that the insides of the two diverging lines are just tangent (making contact at a single point) to the crown of the tree as shown in Figure 21.

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*Photographic scale should be equal to or larger than 1:20,000.

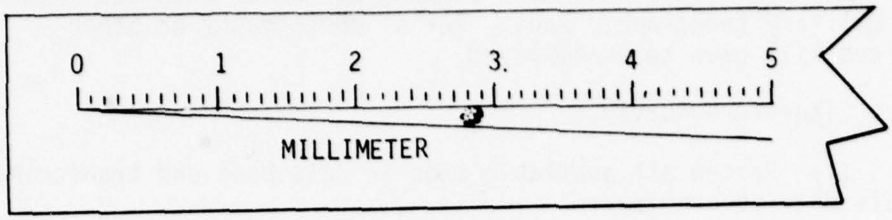

FIGURE 21. Placement of Crown Micrometer Wedge.

b. Take a reading in millimeters at the point on the scale where the tree crown is tangent to the diverging lines.

NOTE: If the crown being measured is asymmetric in outline, two readings should be taken, one at right angles to the other. The high and low reading should then be averaged for a best approximation of crown diameter.

c. Convert photo crown diameter in millimeters to actual diameter of the crown in meters.

Example: Measured photo crown dia. = .8mm

Representative fraction* = 1:12,000

$$\text{Actual Crown Dia.} = \frac{(\text{Photo Dia.})\ (\text{Scale Recip})}{1000}$$

$$\text{Actual Crown Dia.} = \frac{(.8)\ 12{,}000}{1000}$$

$$= 9.6 \text{ meters}$$

2. Dot Type Scale

a. Select a tree for measurement. Slide the scale alongside the tree until a dot is found which is equal in size to the tree's crown (Figure 22). *It is best not to fit the graduated circles over the crown because too much detail is screened by the black line of the circle.*

*Since representative fraction varies with elevation, elevation of the tree being measured must be known.

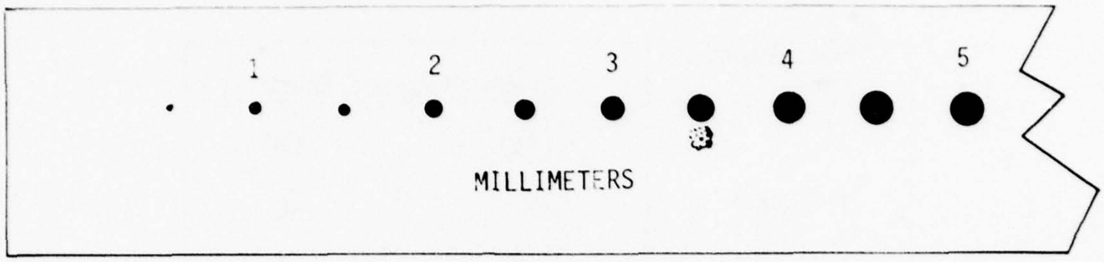

FIGURE 22. Placement of Dot Type Scale.

b. Convert dot size in millimeters to the actual diameter of the crown in meters (See example, Section 1.-c.).

(e) Record the photo measured tree crown diameters for later utilization in stem diameter estimation.

(3) Factors Affecting Accuracy of Crown Diameter Measurement

(a) Photographic scale - The analyst's ability to identify accurately the smallest, average, and largest crown of each map unit is closely associated with photographic scale. This is primarily because small diameter crowns cannot be detected on small scale photography and because clumps of trees tend to be measured as a single crown rather than several small ones.

(b) Location on photograph - Tree crown measurements should be limited to the center portions of photos whenever possible, as they are least affected by distortion. Crown diameters around photo edges should be measured at right angles to the radial line drawn from the principal point through the tree image.

(c) Forest density - crown diameter measurements are most accurate in open grown stands. Measurements in dense stands are usually limited to determination of the crown widths for dominant trees.

(d) Analyst skill - An analyst of average skill should be able to determine accurately the diameter of crowns within each map unit in accordance with the crown diameter ranges shown in Table 9.

TABLE 9. Crown Diameter Accuracy Ranges at Three Photographic Scales.

Photographic Scale	Crown Diameter Range	
	(ft)	(m)
1:20,000	± 5	± 2
1:15,840	± 3	± 1
1:12,000	± 2	0.5 - 1

SOURCE: S. H. Spurr, Photogrammetry and Photo-Interpretation, 2nd Edition, The Ronald Press Company, New York, 1960.

7. Mean Stem Diameter. Tree stem diameter (dbh) is defined as the diameter of a tree at 1.4 m (4.5 ft) above average ground level. Mean stem diameter is calculated for all map units that contain vegetation 2 meters or greater in height.

a. Map Analysis

(1) U.S. - Information necessary to calculate mean stem diameter is not available.

(2) F.R.G. - Information necessary to calculate mean stem diameter is not available.

(3) U.S.S.R. - Mean stem diameter is a stand parameter that is given in meters on some U.S.S.R. topographic maps (Table 5). Transcribe mean stem diameter value to the appropriate column of Vegetation Data Table 1 (Table A1).

b. Literature Survey

(1) Review all available maps in data base and transcribe appropriate data to overlay.

(2) Review all literature, reports, etc., and transcribe appropriate data to overlay.

c. Analysis of Photography

(1) Examine the visible tree crown diameters in the primary canopy of each map unit.

(2) Locate and measure the diameter of the crown that most closely approximates average crown size.

(3) Calculate mean stem diameter by inserting mean crown diameter and/or height data into the appropriate rule of thumb or regression equation located in Appendix B.

(4) Additional details on this procedure are presented in the following section entitled "Number of Trees in Each Stem Diameter Class per Hectare."

(5) Record the mean stem diameter in Vegetation Data Table 1 (Table A1).

8. Number of Trees in Each Stem Diameter Class per Hectare. This data element provides for each map unit the distribution of trees in 5-cm increment stem diameter classes. This distribution is determined graphically and the results recorded in Vegetation Data Table 1 (Table A1).

a. Map Analysis. This data element cannot be obtained from standard military topographic maps. Aerial photography or other data sources will have to be employed.

b. Literature Survey

(1) Review all available maps in data base and transcribe appropriate data to overlay.

(2) Review all literature, reports, etc., and transcribe appropriate data to overlay.

c. Analysis of Photography

(1) Equipment and Materials

Vegetation Data Tables 1 and 2 (Tables A1 and A2) containing map unit information acquired previously on number of trees per hectare, their heights, crown diameters, and, if known, species.

Regression or rule of thumb equations that relate photo-measurable tree parameters, i.e. height and crown diameter to stem diameter (Appendix B).

Five-place logarithm table and/or electronic calculator.

Green drawing paper 8-1/2 by 11 inches (probability by 90 divisions).

Straight edge.

Pencils.

(2) Procedure

(a) Determine the stem diameter distribution in 5-cm increments for each map unit.

1. Locate the regression or rule-of-thumb equation in Appendix B that defines the relationship between stem diameter and tree height/crown width for each species or forest type of interest.

2. Use crown diameter data acquired previously to calculate the stem diameter of three representative trees for each map unit, i.e. those with the largest, average, and smallest crown diameter. Depending upon equation complexity and analyst knowledge, the above calculations may be performed by using logarithm tables or a suitable electronic calculator (see Appendix B for sample calculations).

3. Using probability paper, plot the average dbh at the 50 percent level and the smallest and largest dbh at the 1 and 99 percent levels, respectively (see Figure 23).

Example:

Crown Size	dbh (cm)
Smallest	10
Average	20
Largest	38

4. From the plotted data, determine the percentage of trees in each stem diameter class to the nearest percent. The following data were extracted from the graph constructed in Figure 23.

Stem Diameter Class (cm)

	10-15	15-20	20-25	25-30	30-35	35-40
% of total	12	38	24	16	7	3

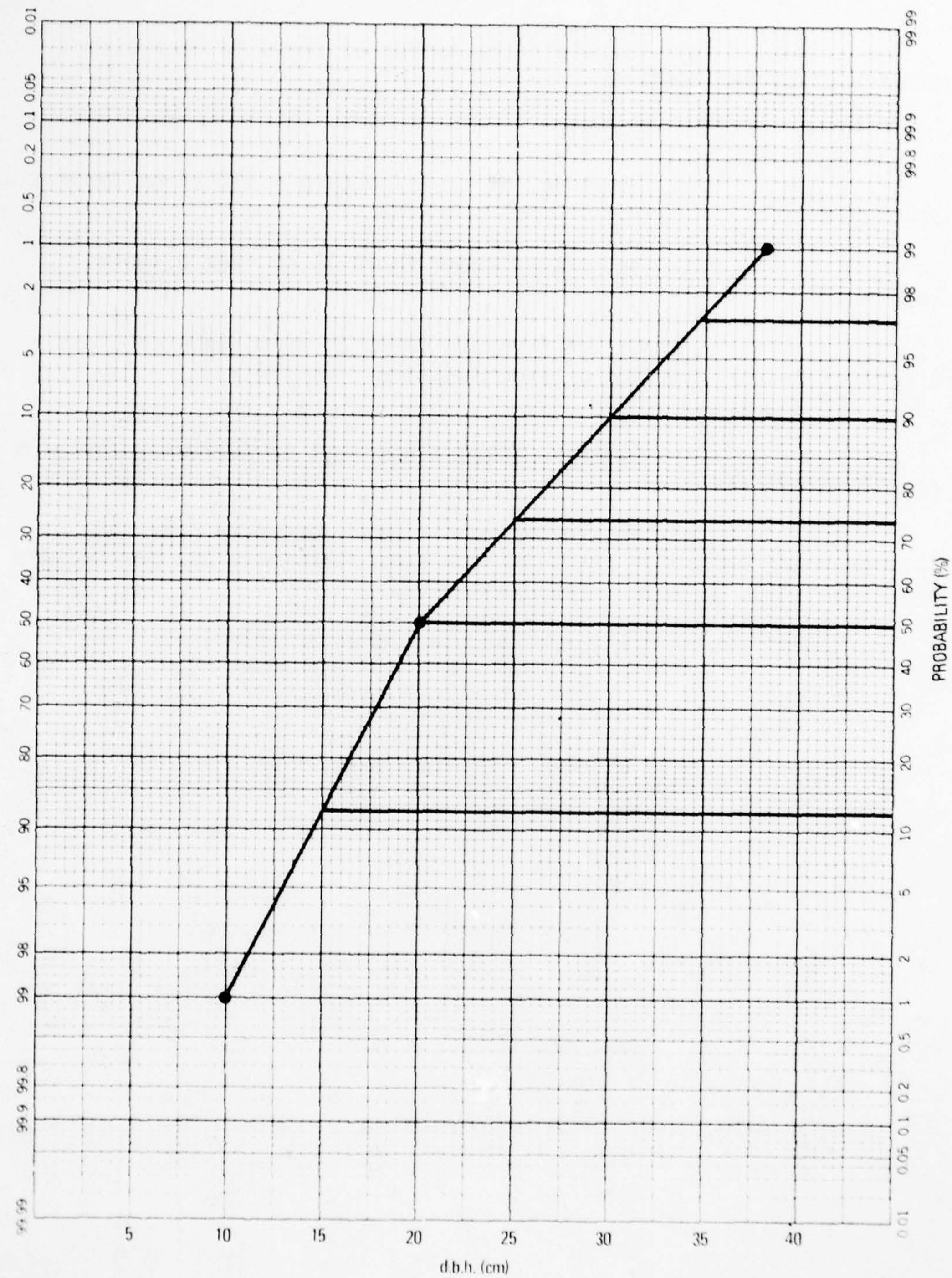

FIGURE 23. Graphic Determination of Stem Diameter Size Distribution.

(b) Calculate the number of trees in each stem diameter class per hectare.

Example:

Total no. of trees/hectare = 312 (from Vegetation Data Table 1).

Percent of trees in 10-15 cm stem diameter class = 12.

No. of trees in 10-15 cm stem diameter class = Percent of total/100 x No. of trees/hectare = 12/100 x 312 = 37 (.12 x 312 = 37).

Similar calculations must be performed for each stem diameter class.

(c) Record the mean stem diameter to nearest centimeter and number of trees in each stem diameter class per hectare in Vegetation Data Table 1 (see Table 10).

TABLE 10. A Portion of Vegetation Data Table 1

MAP UNIT	TOTAL STEMS PER HECTARE	MEAN STEM DIA. (cm)	NUMBER OF STEMS PER DIA. CLASS PER HECTARE																						
			<2 (cm)	2-5 (cm)	5-10 (cm)	10-15 (cm)	15-20 (cm)	20-25 (cm)	25-30 (cm)	30-35 (cm)	35-40 (cm)	40-45 (cm)	45-50 (cm)	50-55 (cm)	55-60 (cm)	60-65 (cm)	65-80 (cm)	70-75 (cm)	80-90 (cm)	90-100 (cm)	100-110 (cm)	110-120 (cm)	120-130 (cm)	130-140 (cm)	140 <
101	430	15			56	155	69	52	43	26	13	5	4												
102	312	20				37	119	75	50	23	9														
103	220	25			28	19	35	26	22	13	7	2	2												
104	175	30			26	17	3	44	26	24	9	7	9	5	2	1									

9. Stem Spacing. This data element provides for each map unit an estimate of the mean distance in meters between adjacent trees. Parameters required for estimation of stem spacing include mean stem diameter and number of trees per hectare.

a. Map Analysis

(1) U.S. - Information necessary for estimation of stem spacing is not available.

(2) F.R.G. - Information necessary for estimation of stem spacing is not available.

(3) U.S.S.R. - Average stem spacing is a stand parameter that is given on some Russian topographic maps. Transcribe this information to the appropriate column of Vegetation Data Table 1 (Table A1).

b. Literature Survey

(1) Review all available maps in data base and transcribe appropriate data to overlay.

(2) Review all literature, reports, etc., and transcribe appropriate data to overlay.

c. Analysis of Photography

(1) Equipment and Materials

Vegetation Data Table 1 (Table A1) containing data acquired previously on total number of stems per hectare and number of trees in each stem diameter class.

Stem spacing estimation equation $\left(S = \sqrt{\frac{12732}{n}}^{\,*} - SD\right)$

(2) Procedure

(a) For each map identification unit, assemble data on total number of stems per hectare and mean stem diameter.

(b) Determine stem spacing to nearest 0.1 meter for each map identification unit (see Table 11).

* $10{,}000\ m^2 = 1$ Hectare n = Number of trees per Hectare

$\frac{10{,}000}{n}$ = area (A) of circle occupied by each tree = $.25\pi D^2$

$$D = \sqrt{\frac{A}{.25\pi}} = \sqrt{\frac{\left(\frac{10{,}000}{n}\right)}{.25\pi}} = \sqrt{\frac{10{,}000}{.25\pi n}} = \sqrt{\frac{10{,}000}{.785\ n}} = \sqrt{\frac{12{,}372}{n}}$$

Example:

TABLE 11. A Portion of Vegetation Data Table 1

MAP UNIT	TOTAL STEMS PER HECTARE	MEAN STEM DIA. (cm)	NUMBER OF STEMS PER DIA. CLASS PER HECTARE																						
			<2 (Cm)	2-5 (Cm)	5-10 (Cm)	10-15 (Cm)	15-20 (Cm)	20-25 (Cm)	25-30 (Cm)	30-35 (Cm)	35-40 (Cm)	40-45 (Cm)	45-50 (Cm)	50-55 (Cm)	55-60 (Cm)	60-65 (Cm)	65-70 (Cm)	70-75 (Cm)	80-90 (Cm)	90-100 (Cm)	100-110 (Cm)	110-120 (Cm)	120-130 (Cm)	130-140 (Cm)	140 +
101	430	15			56	155	69	52	43	26	13	5	4												
102	312	20				37	119	75	50	23	9														
103	220	25			28	79	35	26	22	13	7	2	2												
104	175	30			26	17	3	44	26	24	9	7	9	5	2	1									

1. Using data from map unit 102 above, insert total number stems per hectare and area of sample into stem spacing estimation equation.

Total stems per hectare (10,000 m^2) = 312

$$S = \sqrt{\frac{12732}{n}} - SD$$

S = stem spacing in meters

SD = mean stem diameter in meters = 0.2 m

n = number of stems per hectare

$$S = \sqrt{\frac{12732}{312}} - 0.2$$

2. Divide 12732 by 312

$$S = \sqrt{40.80} - 0.2$$

3. Calculate the square root of 40.80

S = 6.39 - 0.2

4. Subtract mean stem diameter from the calculated stem spacing value.

Mean stem diameter, map unit 102 = 0.20 m

S = 6.39 - 0.20

S = 6.19 meters

5. Round off the stem spacing value to the nearest 0.1 meter and record it in the appropriate column of Vegetation Data Table I (Table A1).

(c) It is easily seen that by knowing the distribution of trees in each stem diameter class, similar calculations can be performed that ignore those trees of stem diameter below a certain critical dimension, e.g. vehicle override diameter.

For example, given the data for map unit 102 in the previous example, calculate the stem spacing for trees 20 cm or larger.

1. Add together the number of trees in each stem diameter class larger than 20 cm.

The number of trees with diameters equal to or greater than 20 cm = 75 + 50 + 23 + 9 = 157.

2. Insert number of trees per hectare equal to or larger than 20 cm and area of sample into stem spacing estimation equation.

$$S = \sqrt{\frac{12732}{n}}$$

$$S = \sqrt{\frac{12732}{157}}$$

3. Perform calculations as described previously in steps (b) 2. - 4.

S = 8.89 meters

4. Determine the mean stem diameter of trees with diameters equal to or greater than 20 cm.

a. Using the graph drawn previously for determinaton of stem diameter size distribution, plot the lower and upper limits of the stem diameter range at the 1 and 99 percent levels respectively (see Figure 24).

b. From the graph, determine the stem diameter that corresponds to the 50 percent probability level.

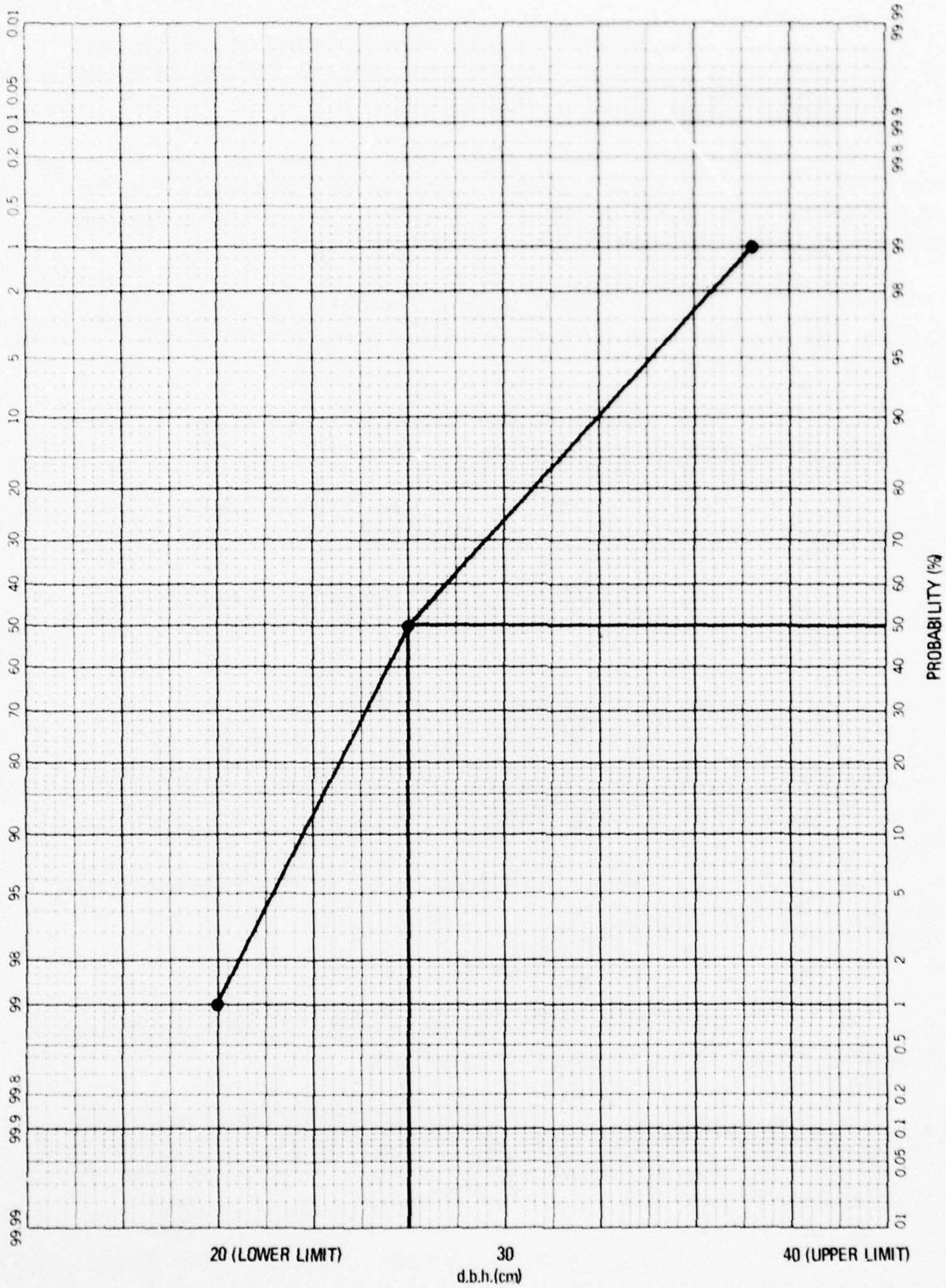

FIGURE 24. Graphic Determination of Mean Stem Diameter

5. Subtract mean stem diameter of the range of interest from the calculated stem spacing value.

Mean stem dia. (range 20 to 40 cm) = 0.27 m

S = 8.89 - 0.27

S = 8.62 meters

6. Round off the stem spacing value to the nearest 0.1 meter and record it in the Vegetation Data Table 1 (Table A1) as appropriate.

10. Species Identification, Seasonality, and Distribution. Species identificaton requires classification of the vegetation in each map unit into specific species. Because of the difficulties often inherent in species discrimination, this procedural guide requires only that vegetation be categorized into broad vegetation types, i.e. broadleaf, needleleaf, and a mixture of these two types. Although not specifically required, species identification should be made where possible.

Seasonality of vegetation concerns changes in the density of tree canopies because of climatic conditions. In temperate climates, temperature has the greatest effect on vegetation, and tropical climates, rainfall has the greatest effect. With the exception of species growing in tropical areas and a few species growing in temperate areas of the world, most broadleaf vegetation loses its leaves in the fall of the year and continues to be dormant until early spring. However in the canopy of needleleaf vegetation, there are only small seasonal differences.

The distribution of plant species within a map unit is a measure of the pattern and the distance between plants of the same species. This data element is difficult to determine from most data sources, but when possible it is recorded in the appropriate column of Vegetation Data Table 2 (Table A2).

a. Map Analysis

(1) U.S.

(a) Detailed species identification is seldom available from U.S. maps. In some special cases, such as mangrove, Nipa palm, etc., the species can be determined; but as a rule only the general vegetation characteristics can be determined from a topographic map. These general characteristics, however, can assist in the interpretation of imagery and collateral sources, and should be recorded during the map interpretation.

(b) Examine the vegetation legend of your source map closely, and compare the legend symbol and description with that appearing in Table 3. Determine the general characteristics of each type of vegetation and record it lightly in pencil in the area on the overlay.

(c) Seasonality cannot be determined from military topographic maps; however, given the geographic location of the area of interest, seasonality can be inferred. For example, in the case of temperate broadleaf stands, estimate the period the stand is in foliage based on the average dates of first and last frost. Record these months in the appropriate column of Vegetation Data Table 2 (Table A2). In the case of evergreen forests, record the months of January and December.

(d) Distribution information cannot be determined from U.S. maps.

(2) F.R.G.

(a) Detailed species information is not available on F.R.G. topographic maps. However, general forest types, i.e. deciduous, coniferous, and mixed are shown that can assist the analyst in the interpretation of aerial imagery and collateral information.

(b) Determine seasonality as indicated in procedure 10a(c) above.

(c) Distribution information cannot be determined from German topographic maps.

(3) U.S.S.R.

(a) Detailed species information is often provided on U.S.S.R. topographic maps. This information is determined and recorded in the following manner: (1) Locate the species name on the topographic map as described in Table 5, (2) translate the name into English with a Russian to English dictionary, and (3) transcribe the species name in the appropriate column of Vegetation Data Table 2 (Table A2).

(b) Determine seasonality as indicated in procedure 10a(c) above.

(c) Distribution information cannot be determined from U.S.S.R. topographic maps.

b. Literature Survey

(1) Review all available maps in data base and transcribe appropriate data to overlay.

(2) Review all literature, reports, etc., and transcribe appropriate data to overlay.

c. Analysis of Photography

(1) Equipment and Materials

Stereoscope, folding pocket type.

Vertical aerial photographic prints of area of interest with approximately 60 percent end overlap and 30 percent lateral overlap.*

Vegetation key that characterizes tree species likely to be found in area of interest (see Appendix B).

Magnification tube.

Vegetation Data Table 2.

Masking tape.

(2) Procedure

(a) Orient stereo pair for viewing. Securely fasten stereo mate (alternate photo) to clear acetate overlaying the photo mosaic.

(b) Study all trees occurring in the primary canopy (2 m or greater in height) and located within the field of view. Take into consideration their physical appearance, site characteristics, tone, etc.

(c) Select the appropriate vegetation identification key from Appendix B. Read over the key several times to determine the type of information utilized in species discrimination.

NOTE: If a suitable vegetation identification key is unavailable and the analyst has no alternate means of species identification on large scale photography, other available information sources must be relied upon, i.e. literature and maps.

(d) Determine tree species found within each map identification unit. Assign a single letter code to each species identified. Record this letter, e.g. a, b, or c, in the second column of Vegetation Data Table 2 (see Table 12).

*Photographic scale should be equal to or larger than 1:10,000.

TABLE 12. A Portion of Vegetation Data Table 2

MAP UNIT IDENTIFICATION	SPECIES DATA						
	CODE	SPECIES IDENTIFICATION: SCIENTIFIC NAME	ENGLISH NAME	LOCAL NAME	SEASONALITY	% OF STAND	DISTRIBUTION PATTERN
1	a	LIRIODENDRON TULIPIFERA	YELLOW POPLAR	TULIP TREE	MAY - OCT	50	BROADCAST RANDOM
	b	LIQUIDAMBAR L	SWEET GUM	RED GUM	MAY - OCT	30	
	c	ILEX OPACA	HOLLY	HOLLY	JAN - DEC	10	
2	a	PINUS L	VIRGINIA PINE	PINE	JAN - DEC	40	BROADCAST
	b	LIRIODENDRON TULIPIFERA	YELLOW POPLAR	TULIP TREE	APR - OCT	20	CLUSTERS BROADCAST
	c	LIQUIDAMBAR L	SWEET GUM	RED GUM	MAY - OCT	25	
	d	CORNUS L	DOGWOOD		MAY - OCT	10	
3	a	PINUS L	VIRGINIA PINE	PINE	JAN DEC	75	BROADCAST
	b	FAGUS	BEECH	BEECH	MAY - DEC	10	BROADCAST

(e) Record each species' scientific, English, and, if known, local name in the appropriate columns of Vegetation Data Table 2 (Table 12).

(f) Determine seasonality (months during which trees are fully leaved) by locating in the literature average dates of first flowering and first frost. Record these dates to the nearest month in the appropriate columns as shown above. In the case of the evergreen trees, e.g. pine and hemlock, the months of January and December are recorded.

(g) Stereoscopically estimate the percentage of map unit area occupied by each identifiable tree species. Record this information in the appropriate column of Table 12. Percentages will not always total 100 percent because of inability to identify all species.

(h) Classify the distribution of each species within the map unit area into one of the categories listed below. Record the appropriate descriptive term in the column labeled Distribution Pattern.

Vegetation Distribution Pattern	Definition
Random	Irregularly spaced individual and small groups of plants
Broadcast	Irregularly spaced individual plants
Clusters	Plants in groups, but mechanically independent; plant shape not affected by association

Vegetation Distribution Pattern	Definition
Clumps	Plants in close association; stems independent; plant shape affected by association
Grids	All plants approximately equally distant from nearest neighbor
Hills	Plants grouped in mounds of earth with groups spaced regularly
Rows	Plants closely spaced in one direction much more widely spaced in another
Strips	Elongated patches of vegetation

(3) Factors Affecting Ability to Identify Species

(a) Photo Scale - Species identification demands imagery of 1:10,000 or larger. Some vegetation keys identify tree species by crown characteristics, which can be properly evaluated only with imagery as large as 1:2,000. If large scale imagery cannot be obtained, reliable species identification is not feasible from imagery.

(b) Analyst Experience - Vegetation interpretation experience is an invaluable asset when attempting identification of tree species. Available vegetation keys often require considerable knowledge of the ecological requirements of each tree species. For example, identification is often made, not by recognition of a unique physical characteristic of the species, but by inference from environmental conditions, i.e. topographic setting, aspect, and ground conditions. Patterns that indicate a recent disturbance, such as fire or clearing for agriculture, also serve as clues to which tree specie or species are present. Each bit of information, of little value taken individually, is pieced together by the experienced analyst to form a recognizable pattern that is clearly representative of a specific species.

(c) Geographic Area - Location of the area of interest markedly affects the difficulty of species identification because of great species diversity in some parts of the world. For example, in northern boreal forests, species identification is relatively easy with perhaps five different tree species per hectare. In contrast, a forested hectare in tropical environments may contain 50 different tree species, each represented by as few as three or four trees. This natural diversity greatly increases species identification difficulty.

(d) Film Type - Because species identification is, in general, based upon slight physical or spectral reflectance differences, film type selection is critical to successful species differentiation. Generally, the best discrimination between species is obtained with aerial color infrared film because of its ability to portray differences in spectral reflectivity in the near infrared portion of the light spectrum. The drawback to its use is that relatively small areas of the world have been imaged with large scale, color infrared film. Large scale aerial color and black and white infrared imagery are also good for species discrimination; however, neither type of imagery is readily available. The film type that is most economical and therefore most readily obtainable is black and white panchromatic, which is least useful for species identification. Using this film type, as well as the others mentioned, is increased if the forested areas are imaged when species reflectance differences are maximized, generally in the spring and fall in temperate climates.

11. Ground Cover Type, Percent of Cover, and Height. The ground cover type data element refers to vegetation that includes grasses, as well as woody and non-woody plants, less than 2 meters in height. This vegetation is found both in open areas and under overlying forest canopies. Identification is by common name, e.g. shrubs, vines, grasses, etc. Scientific terms should be avoided.

The percent cover data element is defined as the percentage of ground areas occupied by each type of plant occurring within a map unit. The time period during which these plants will give the greatest ground coverage is indicated by recording the abbreviations of the first and last months of the period.

The time period during which the plants reach their maximum height is indicated by recording the abbreviation of the first and last months of the period. Estimations of maximum height are to the nearest 0.5 meters (Figure 25).

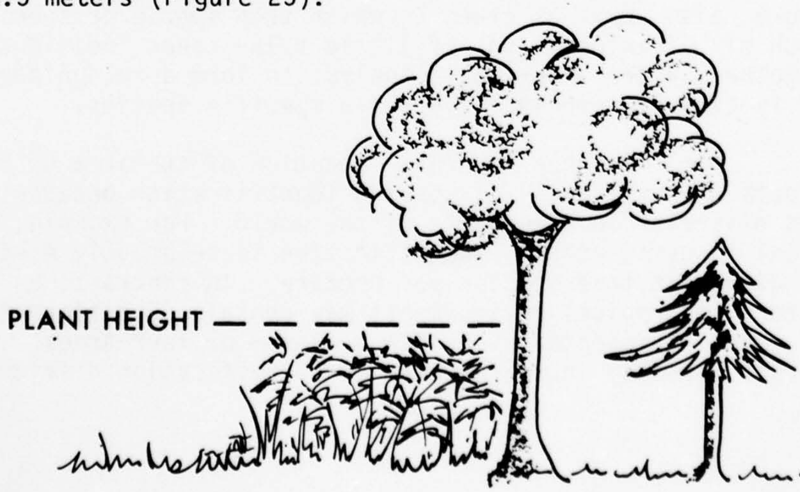

FIGURE 25. Ground Cover.

a. Map Analysis. These data elements can not be obtained from standard military topographic maps. Aerial photography or other data sources will have to be employed.

b. Literature Survey

(1) Review all available maps in data base and transcribe appropriate data to overlay.

(2) Review all literature, reports, etc., and transcribe appropriate data to overlay.

c. Analysis of Photography

(1) Equipment and Materials

Stereoscope, folding pocket type.

Vertical aerial photographic prints of area of interest with approximately 60 percent end lap and 30 percent side lap.*

Magnification tube.

Masking tape.

Vegetation Data Table 2 (Table A2).

(2) Procedure

(a) Orient stereo pair for viewing. Securely fasten stereo mate (alternate photo) to clear acetate overlaying photo mosaic.

(b) Evaluate each map unit as to type of ground cover, e.g. shrub, grass, blackberry bushes, etc. Remember ground cover, as defined in this procedural guide, is vegetation of less than 2 meters in height.

(c) Record the type of ground cover and name, if known, in Data Table 2 (as shown in Table 13).

*Photographic scale should be equal to or larger than 1:10,000.

TABLE 13. A Portion of Vegetation Data Table 2.

GROUND COVER					
TYPE	NAME	MAX. % COVER		MAX. HEIGHT	
		MONTH	%	MONTH	HEIGHT (m)
SHRUB	LARUEL	JAN-DEC	5	JAN-DEC	2
VINE	VA. CREEPER	JUN-OCT	20	JUN-OCT	20

(d) Determine ground cover height to the nearest 0.5 meters and percent cover to the nearest 10 percent for each map identification unit. If imagery was not acquired during height of growing season, estimates made from the photography must be modified to reflect maximum height and percent cover conditions. Record these estimates in the appropriate column of Vegetation Data Table 2 (Table A2).

(e) Use collateral source material, such as that found in Appendix D-2, to determine months of maximum height and percent cover. Record these months in the appropriate column of Vegetation Data Table 2 (as shown in Table 13).

12. Litter Type and Depth. The term "litter" refers to the unconsolidated material that is found covering the soil surface beneath vegetation. In most texts on soil stratigraphy, litter is referred to as the Ao layer (Figure 26). Needleleafed forests produce litter composed of dead needles, pine cones, and small bits of bark and limbs.

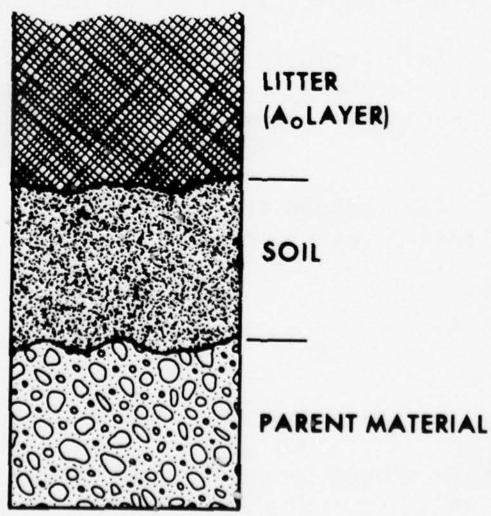

FIGURE 26. Soil Profile.

AD-A068 715 ARMY ENGINEER TOPOGRAPHIC LABS FORT BELVOIR VA F/G 8/6
TERRAIN ANALYSIS PROCEDURAL GUIDE FOR VEGETATION.(U)
MAR 79 J A MESSMORE, T C VOGEL, A R PEARSON
UNCLASSIFIED ETL-0178 NL

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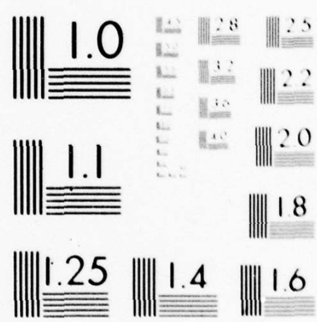


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

a. Map Analysis

(1) U.S. - Information necessary for determination of litter type and depth is not available.

(2) F.R.G. - Limited information concerning litter type may be inferred because coniferous, deciduous, and mixed forests are characteristically associated with certain types of litter. For example, broadleaves and needleleaves are associated with deciduous and coniferous tree species respectively. Both broad and needle leaves comprise litter in mixed tree stands. Information necessary for calculation of litter depth is not available.

(3) U.S.S.R. - Limited information concerning litter type may be inferred because coniferous, deciduous, and mixed forests are characteristically associated with certain types of litter. For example, broadleaves and needleleaves are associated with deciduous and coniferous tree species respectively. Both broad and needle leaves comprise litter in mixed tree stands. Information necessary for calculation of litter depth is not available.

b. Literature Survey

(1) Review all available maps in data base and transcribe appropriate data to overlay.

(2) Review all literature, reports, etc., and transcribe appropriate data to overlay.

c. Analysis of Photography

(1) Equipment and Materials

Stereoscope, folding pocket type.

Magnification tube.

Large scale vertical aerial photographic prints of area of interest with approximately 60 percent end lap and 30 percent side lap.*

Vegetation Data Table 2 (Table A2).

(2) Procedure

(a) Although detailed information on litter type cannot be obtained by examining large scale aerial photography, an estimate of litter type, i.e. broadleaves, needleleaves, dead twigs, etc., can be made provided the analyst can see the forest floor.

*Photographic scale should be equal to or larger than 1:5,000.

(b) Record information in Vegetation Data Table 2 (Table 14).

TABLE 14. A Portion of Vegetation Data Table 2.

MAP UNIT IDENTIFICATION	CODE
	a
1	
	b
2	c

LITTER		
TYPE	MAX. DEPTH	
	MONTH	DEPTH (cm)
LEAVES	NOV	25
LEAVES	NOV	25
NEEDLES	JAN-DEC	5

(c) Use collateral source material to obtain data on maximum litter depth and month of its occurrence, as this information cannot be determined from aerial photography.

NOTE: Tropical climates with characteristic luxuriant vegetation favor little or no litter accumulation owing to rapid decomposition of organic matter. Similarly, accumulation of litter in the deciduous forests of the U.S. is small - seldom exceeding 1 inch in depth.[9] In contrast, cool northerly climates or predominately needleleafed trees support accumulation of organic matter owing to slow decomposition rates.

13. Mean Height to Lowest Branches. This data element is defined as the average or mean distance measured from ground level to the first or lowest branches of trees within a given map unit (Figure 27).

[9] J. E. Weaver and F. E. Clements, Plant Ecology, McGraw-Hill Book Company, Inc., New York, NY, 1938.

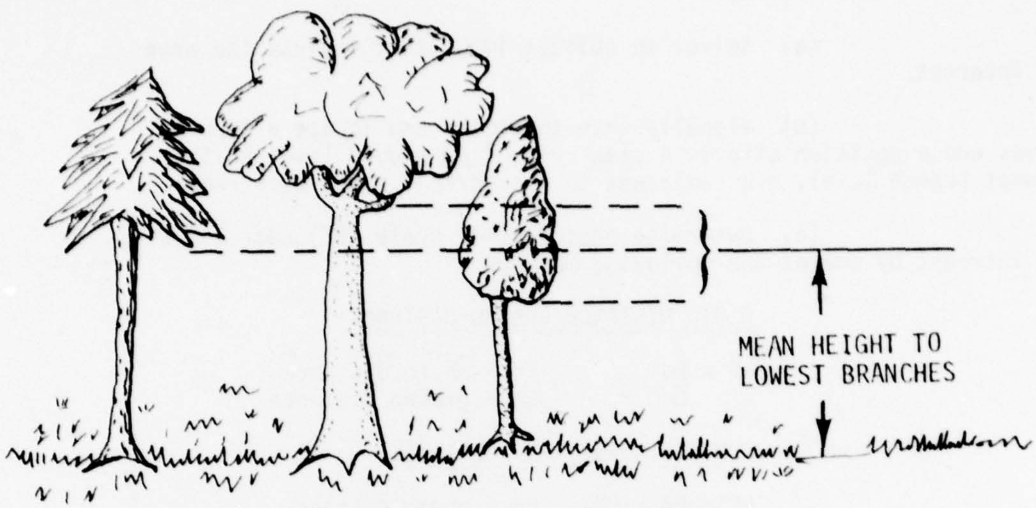


FIGURE 27. Mean Height to Lowest Branches.

a. Map Analysis. This data element cannot be obtained from standard military topographic maps. Aerial photography or other data sources will have to be employed.

b. Literature Survey

(1) Review all available maps in data base and transcribe appropriate data to overlay.

(2) Review all literature, reports, etc., and transcribe appropriate data to overlay.

c. Analysis of Photography

(1) Equipment and Materials

Stereoscope, folding pocket type.

Large scale oblique aerial photographic prints of area of interest.

Engineer's scale.

Magnification tube.

Vegetation Data Table 1 (Table A1).

(2) Procedure

(a) Select an oblique image that depicts the area of interest.

(b) Visually scan the image and locate a tree or trees whose position affords a clear view from ground level to the lowest branch level, e.g. adjacent to a clearing, road, or stream.

(c) Determine photographic scale (RF) near the area of interest by one of the following methods:

PHOTO DISTANCE/GROUND DISTANCE

$RF = \frac{Pd}{Gd}$ — Pd = photo distance, Gd = ground distance

PHOTO DISTANCE/MAP DISTANCE

$RF = \frac{Pd}{Md} \times MRF$ — Pd = photo distance, Md = map distance, MRF = RF of map

When measuring photo distances to determine scale, the analyst should measure features that are (1) parallel to the flight line if photo is a left or right oblique, and (2) perpendicular to the flight line if photo is a forward oblique.

(d) Use an engineer's scale or similar measuring device to determine the photo distance from ground level to lowest branch level in millimeters.

(e) Calculate the height to lowest branches to nearest 0.1 meter. Example:

Photo scale = 1:3,000.

Photo measured height to lowest branches = 1 mm

$$\text{Height to lowest branches} = \frac{\text{Photo distance (mm)}}{1} \times \frac{1}{\text{Photo Scale}}$$

$$\times \frac{1m}{1000mm} = \frac{1}{1} \times \frac{1m}{1000} = \frac{1}{1} \times \frac{3}{1} \times 1m = 3.0m$$

Alternate Method

If the approximate height of the trees being measured is known, a proportion incorporating total tree height can be used.

Example:

Tree height = 15 m

Photo measured tree height = 5 mm

Photo measured height to lowest branches = 2 mm

$$\frac{\text{Height to lowest branches (X)}}{\text{Tree Height (m)}} =$$

$$\frac{\text{Photo measured height to lowest branches (mm)}}{\text{Photo measured tree height (mm)}}$$

$$\frac{X}{15\text{ m}} = \frac{2}{5}$$

$$5X = 30\text{ m}$$

$$X = 6.0\text{ m}$$

(f) If possible, estimate the mean height to lowest branches for each map identification unit.

(g) Insert the estimated values into Vegetation Data Table 1 (see Table 15)

TABLE 15. A Portion of Vegetation Data Table 1

Map Unit Identification	Mean Height (m)		% Canopy Closure by Season			
	Top of Canopy	Lowest Branches	Dec-Feb	Mar-May	Jun-Sep	Oct-Dec
101	20	3.0				
102	23	3.2				
103	30	4.1				
104	27	3.5				

14. <u>A Representative Transect</u>. This data element is a carefully drawn illustration of a cross section of each map unit showing stem spacing, relative tree height, height to lowest branching, crown diameter, shape of the individual trees, etc. (Figure 28). The transect length is variable and dependent upon the distribution and complexity of the vegetation. An effort should be made to illustrate accurately all characteristics of the vegetation located in each map unit.

FIGURE 28. A Representative Vegetation Transect.

a. Map Analysis. This data element cannot be obtained from standard military topographic maps. Aerial photography or other data sources will have to be employed.

b. Literature Survey

(1) Review all available maps in data base and transcribe appropriate data to overlay.

VEGETATION DATA TABLE 2
SPECIES DATA, GROUND COVER, AND LITTER

MAP UNIT IDENTIFICATION	SPECIES DATA							GROUND COVER					
	CODE	SPECIES IDENTIFICATION			SEASONALITY	% OF STAND	DISTRIBUTION PATTERN	TYPE	NAME	MAX. % COVER		MAX. HEIGHT	
		SCIENTIFIC NAME	ENGLISH NAME	LOCAL NAME						MONTH	%	MONTH	HEIGHT (m)
1	a	LIRIODENDRON TULIPIFERA	YELLOW POPLAR	TULIP TREE	MAY - OCT	50	BROADCAST	SHRUB	LARUEL	JAN - DEC	5	JAN - DEC	2
							RANDOM	VINE	VA CREEPER	JUN - OCT	20	JUN - OCT	20
	b	LIQUIDAMBAR L	SWEET GUM	RED GUM	MAY - OCT	30							
	c	ILEX OPACA	HOLLY	HOLLY	JAN - DEC	10							
2	a	PINUS L	VIRGINIA PINE	PINE	JAN - DEC	40	BROADCAST	SHRUB	POISON IVY	JUNE	40	JUN - OCT	1
	b	LIRIODENDRON TULIPIFERA	YELLOW POPLAR	TULIP TREE	APR - OCT	20	CLUSTERS	VINE	HONEYSUCKLE	JUNE	35	JUN - OCT	5
							BROADCAST	BRAMBLES	BLACKBERRY	JUN - NOV	20	JUL - NOV	1.5
	c	LIQUIDAMBAR L	SWEET GUM	RED GUM	MAY - OCT	25							
	d	CORNUS L	DOGWOOD		MAY - OCT	10							
3	a	PINUS L	VIRGINIA PINE	PINE	JAN - DEC	75	BROADCAST	BRAMBLES	BLACKBERRY	JUN - NOV	50	JUL - NOV	1.5
	b	FAGUS	BEECH	BEECH	MAY - DEC	10	BROADCAST						

REPRESENTATIVE TRANSECT

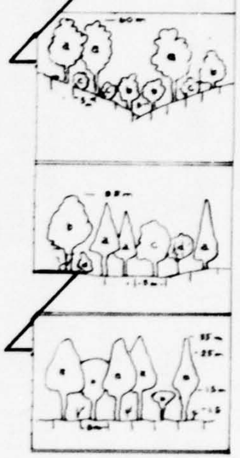


TABLE 16. A Portion of Vegetation Data Table 2

(2) Review all literature, reports, etc., and transcribe appropriate data to overlay.

c. Analysis of Photography

Most of the information needed for construction of a representative transect (map unit cross section) has been previously derived for other data elements. This information includes canopy height, canopy closure, forest type, species data, tree spacing, topographic relief, and ground cover type. Crown shape, which must be graphically depicted on the transect, can also be estimated from large scale vertical aerial photography, although oblique photography provides more complete information. General crown shape can also be determined from the illustration in a local dendrology textbook,* provided the analyst is able to identify species groups, such as poplar, pine, and hemlock, from the photography.

Application of the above information to the problem of developing a representative transect requires that an analyst has experience and has a knowledge of local vegetation conditions. This is true because aerial imagery does not provide a ground view of the vegetation, and therefore extension/assimilation of the available remotely acquired information is necessary.

Vegetation shown in the constructed transect is identified by placing the forest type/species code, e.g. a, b, c, etc. within the crown area. Vegetation Data Table 2 (Table 16) illustrates code placement and type of information included in the transect. Place a legend or key to the letter codes at the bottom of the data table.

*A botanical study of trees encompassing their description, classification, and geographic distribution.

APPENDIX A. SPECIFICATIONS FOR THE PREPARATION OF FACTOR OVERLAYS

I. Objectives and Design Elements Common to All Factor Overlays

A. Objectives

The objectives of this section are to establish the operational concepts for the production of factor overlays and to prescribe the design and formats for those elements and components common to all factor overlays.

B. Operational Concepts

1. Factor overlays are intended primarily for use within the mapping and intelligence community, and in addition as quick reaction terrain products for distribution to the user.

2. Factor overlays provide formatted geographic data that can be readily retrieved and used in various combinations for terrain analysis and for production of special terrain products.

3. Factor overlays will be prepared in the form of stable base overlays that will accept photographic reduction to 70 by 105 mm and retain their legibility when enlarged back.

4. Normally each data field will require several factor overlays for each area. Data elements to be portrayed on each factor overlay, the symbology to be employed, and unique formats are specified separately for each data field.

5. These specifications do not treat methods of collecting or reducing data. Their purpose is to specify the manner of graphically recording collected and reduced data.

C. Format

1. General format specifications are indicated in Figures A-1 and A-2.

2. No single factor overlay will exceed 660 by 860 mm (26 by 34 inches), including titles, legends, and other marginal data. Where use of a base map exceeding these dimensions is desired, the base will be subdivided and separate factor overlays prepared for each part. When an oversized base is subdivided, each subdivision will be assigned an identification and an index of parts prepared as per Figures A-1 and A-2.

3. Whenever possible, factor overlays will be registered to a standard scale U.S. military map. Base maps other than U.S. military maps will be clearly identified in the upper right corner of the factor overlay.

4. Each factor overlay will be punch registered to the base map at the four corners of the neat line.

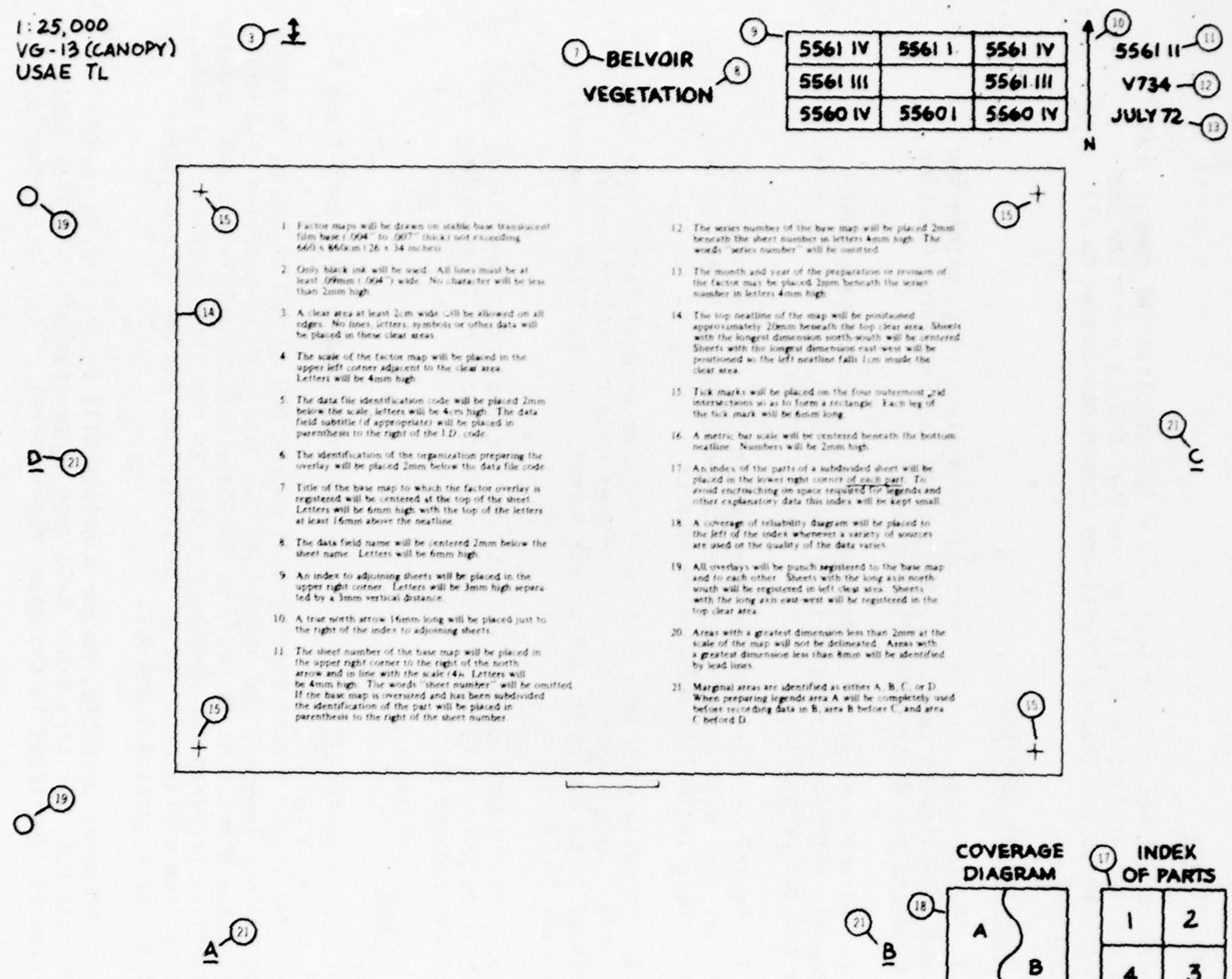


FIGURE A-1. Format for Factor Maps with Long Axis E-W.

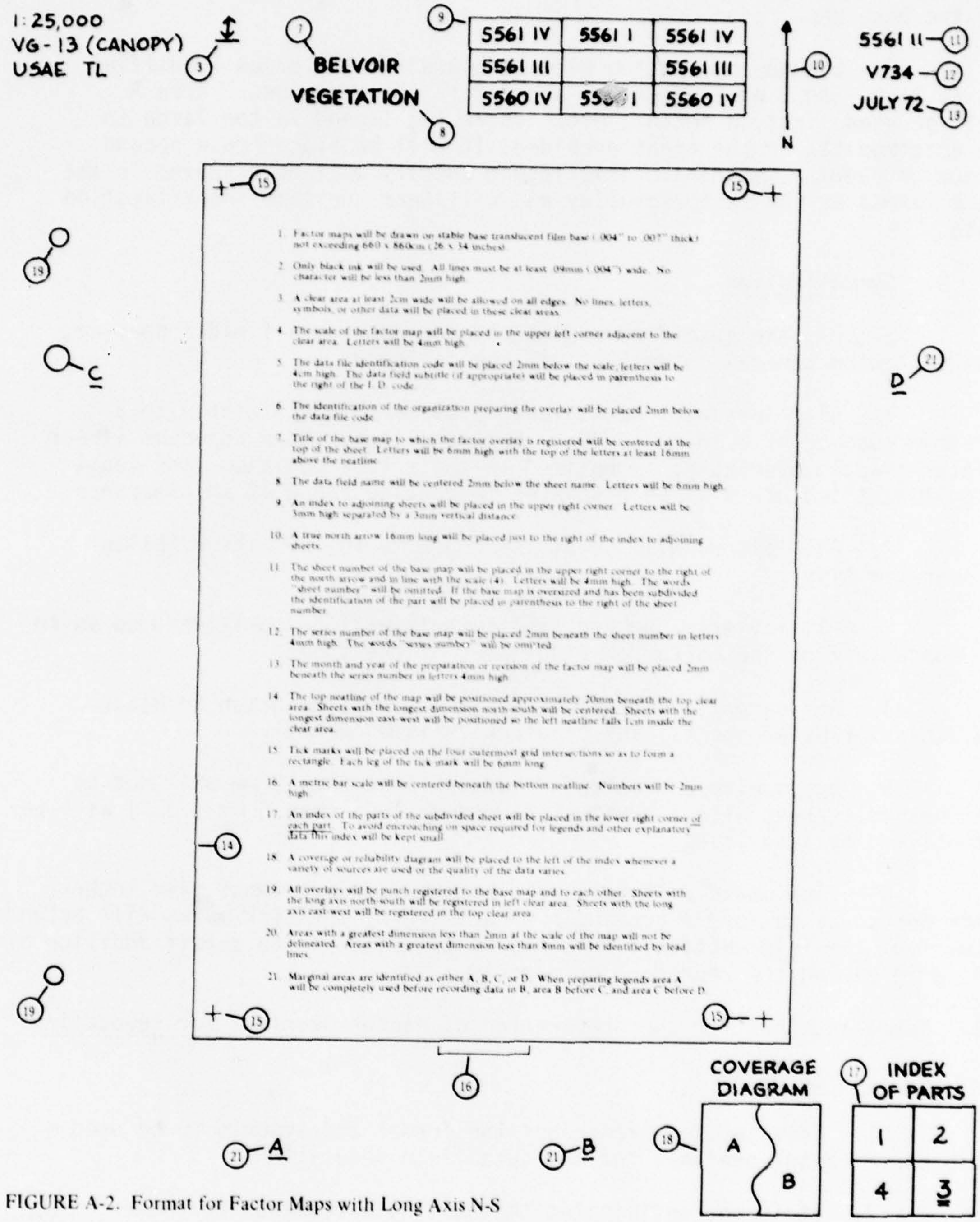


FIGURE A-2. Format for Factor Maps with Long Axis N-S

5. A neat line 0.5 mm wide will be placed on each factor overlay. This neat line will normally coincide with the neat line of the base map.

6. Legend information will be placed on the areas identified as A, B, C, and D on Figures A-1 and A-2 in that sequence. Area A will be used first, B second, etc. Where the legend is too large to be accommodated in the areas provided, it will be placed on a second piece of overlay material. This legend overlay will be prepared in the same format as the factor overlay and will bear the same identification data.

D. Symbolization

Symbols are specified separately for each data field. However, the following general guidelines will be followed:

1. All lines will be at least 0.09 mm (0.004") wide with a minimum spacing of 0.18 mm (0.008") between lines. When adjacent linear features would overlap if symbolized in their true position, the least significant feature will be displaced to provide the 0.18 mm clearance.

2. All letters will be at least 3.2 mm (0.125") high (Elite typewriter type).

3. All letters, numbers, and symbols will be positioned so as to be readable from the bottom or right side of the sheet.

4. All symbols, letters, and numbers will be drawn in black (plastic for Mylar sheets) ink or black "Prisma" pencil.

5. Areas with a greatest dimension less than 2 mm will not be delineated. Areas with a greatest dimension less than 8 mm (.32") will be identified by lead lines.

6. Tick marks will be placed on the four outermost grid intersections so as to form a rectangle. Each leg of the tick marks will extend 3 mm from the intersection. These ticks are required to permit addition of the grid during the reproduction process.

II. Specifications for the Preparation of Factor Overlays for Vegetation

A. Introduction

1. This section prescribes the format and symbols to be used to prepare factor overlays for the data field Vegetation.

2. It is not anticipated that all data required by these specifications will be available during the initial preparation of a factor map. Lack of complete data, however, should not preclude preparation

of the factor overlay. The factor overlay concept envisions the systematic recording of data as it is acquired, periodic revision of the overlays, and the accumulation of data over a period of time.

B. General Description. The vegetation factor overlays will consist of two parts as follows:

1. An overlay registered to a 1:50,000 scale map with areas of uniform vegetation conditions outlined and identified (Figure A3). The vegetation type, maximum canopy closure, and mean height to the top of the canopy will be provided for each area.

2. A series of accompanying data tables describing the vegetation conditions within each area (Tables A1 and A2).

C. Data Elements. The following data elements will be presented by the factor overlay and accompanying tables:

1. Map unit identification/vegetation boundaries.
2. Mean height to top of canopy.
3. Percent canopy closure.
4. Number of stems per hectare.
5. Tree crown diameter.
6. Mean stem diameter.
7. Number of trees in each stem diameter class per hectare.
8. Stem spacing.
9. Species identification, seasonality, and distribution.
10. Ground cover type, percent of cover, and height.
11. Litter type and depth.
12. Mean height to lowest branches.
13. A representative transect.

D. Format

1. Factor Overlay (Figure A-3)

a. The general format for the factor overlay will be as prescribed in Section I of this appendix.

b. Source(s) used in the preparation of the factor overlay and tables will be entered in section B (Figures A-1 and A-2) to the

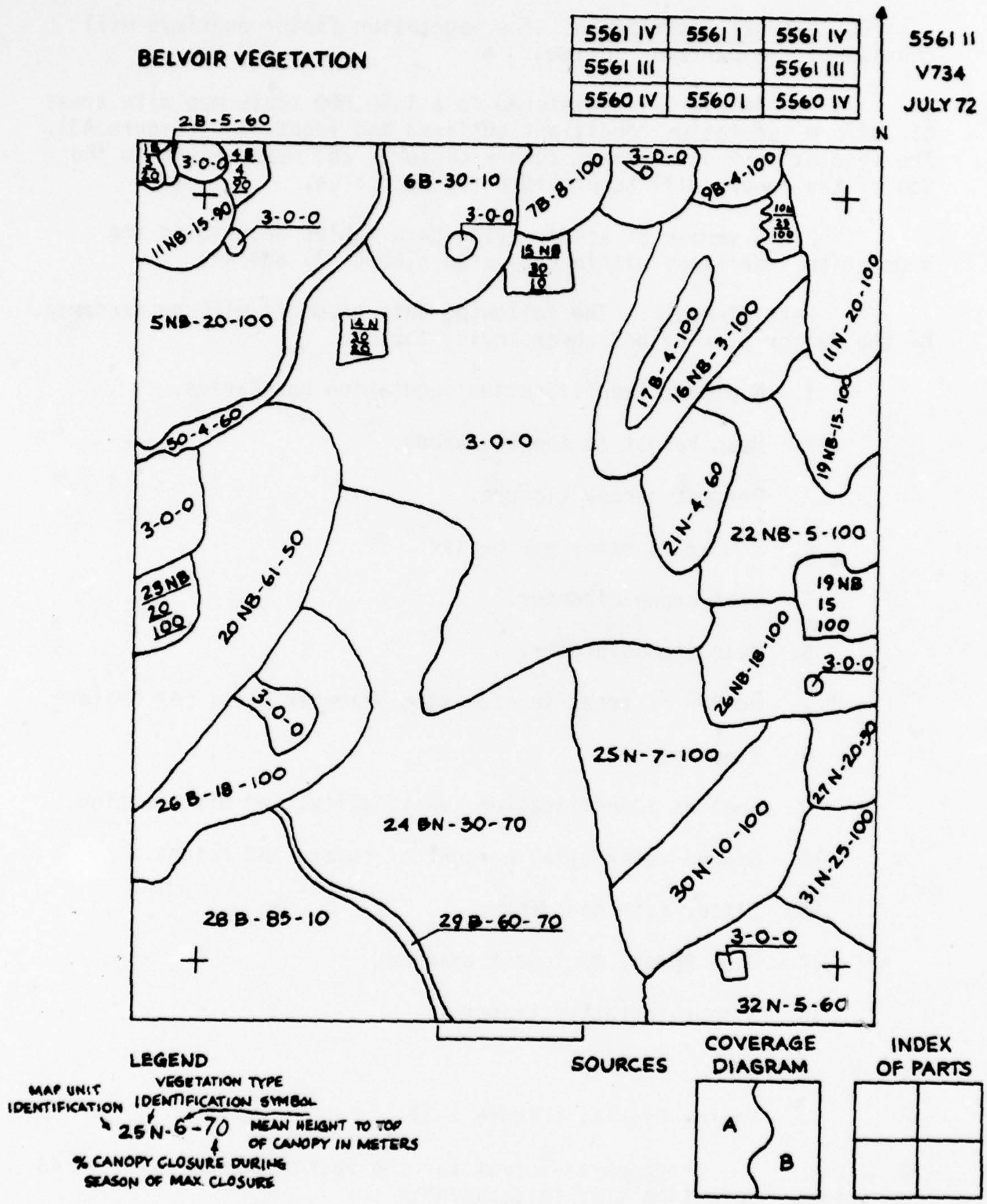


FIGURE A-3. Sample Factor Overlay

left of the coverage diagram when they are not adequately described in the coverage diagram. Where a single source is used or all sources apply to the entire sheet, the coverage diagram may be replaced by the source listing.

c. The following legend will be placed in Section A of the margin (Figures A-1 and A-2).

LEGEND

Map Unit Identification — Vegetation Type Identification Symbol

101N - 10 - 80

Average Height to Top of Canopy in Meters

% Canopy Closure During Season of Greatest Closure

Alternate Treatments: $\frac{101N}{\frac{10}{80}}$ $\frac{101N}{10\text{-}80}$ $\frac{\frac{101N}{10}}{80}$

2. Data Tables (A1 and A2)

a. The general format of the data tables will be as prescribed in Section I of this Appendix.

b. Where the number of map units will permit, Tables A1 and A2 will be placed on a single overlay as indicated in the sample factor overlay (Figure 3). When the number of map units is too great to permit placing all tables on a single overlay, a separate overlay will be prepared for each table.

c. The index to adjoining sheets, coverage diagram, and source listings will be omitted from the data table overlays.

E. Symbolization

1. Factor Overlay (Figure A-3)

a. Each area of uniform vegetation conditions will be outlined in a solid line 0.2-mm wide and assigned an identification number. Identification numbers will be assigned sequentially from left to right starting in the upper left corner.

b. The map unit identification number, vegetation type identification symbol, percent canopy closure during the season of greatest closure, and the mean height to the top of canopy in meters will be entered in each map unit area in black letters at least 3.2 mm high.

c. Where the area being described has no plants 2 meters or greater in height, the canopy closure and plant height will be symbolized by zeros.

2. Data Tables

a. Vegetation Data Table 1 (Table A1)

(1) Data appearing in this table applies only to plants 2 meters or greater in height. Information on plants less than 2 meters high will be treated in Data Table 2 under "Ground Cover."

(2) Map Unit Identification: Identification numbers will be listed in numerical sequence in the first column of the table.

(3) Number of Stems/Hectare: The total number of stems per representative hectare will be recorded in column two.

(4) Mean Stem Diameter: The mean stem diameter of each map unit will be recorded in the appropriate column.

(5) Stem Spacing: The mean distance in meters between adjacent trees will be recorded in the appropriate column.

(6) Number of Trees in Each Stem Diameter Class per Hectare: The number of trees in each stem diameter class within a representative hectare will be recorded in the appropriate diameter class columns. Diameters will be determined at breast height (1.4 meters).

(7) Mean Height: The mean height to the top of canopy and the lowest branches of the foliage mass will be recorded in the last two columns. The mean height to the top of the canopy must be the same as that recorded on the factor map.

(8) Percent Canopy Closure by Season:

(a) The seasons affecting plant growth will be determined and indicated at the top of the columns by recording the abbreviations for the first and last month of each season.

(b) The prevailing canopy closure of the primary canopy will be recorded in the appropriate column in percent.

b. Vegetation Data Table 2 (Table A2)

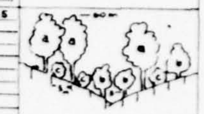
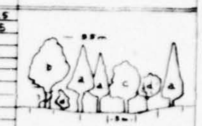
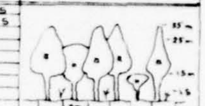
(1) Map Unit Identification: Identification numbers will be listed in numerical sequence in the first column.

VEGETATION DATA TABLE 1
STEM DIAMETERS AND HEIGHTS OF CANOPY

MAP UNIT IDENTIFICATION	TOTAL SYSTEMS HECTARE	MEAN STEM DIAM (cm)	NUMBER, EACH STEM DIAMETER CLASS PER HECTARE <1 (cm)	1-2 (cm)	2-3 (cm)	3-4 (cm)	4-5 (cm)	5-6 (cm)	6-7 (cm)	8 (cm)	8-9 (cm)	9-10 (cm)	10-12 (cm)	12-14 (cm)	14-16 (cm)	16-18 (cm)	18-20 (cm)	20-25 (cm)	25-30 (cm)	30-35 (cm)	35-40 (cm)	40-45 (cm)	45-50 (cm)	50-60 (cm)	60-70 (cm)	70-80 (cm)	85-100 (cm)
1	1000	17.7		182						200			22	16	78		210	80	150	100		8		5			
2	675	13							120			210	50					120				110			15		
4	500	31.4								5				50				30		50			100			25	
5	850	21.							25			190		180		65		130	50	210							
6	565	16.					185	30			30				75	120		50			85	210					
7	337	20.											75	110	45		230		80	112			115	60	35		
8	500	25.5				8												4			80	50		100			35
9	1800	17.8			184				200		22		28		15			210	180		150	180		8	5		
10	950	14.5					180		40			135	70			125		85		220						75	
11	875	19.6						182		110	210			50			120										
12	350	5.					50		5				50						30		50		110	100	25	15	
13	530	10		75	183		60	250		80	111		175	60	35												
15	975	5.		75	250	40	112	60			115		85				60	118									
16	735	8.		160		80	115		55	40		60				55											
17	675	19						120			210			50			120			110				15			
18	550	8		75		180	40			135	175			70		25		175									

MAP UNIT IDENTIFICATION	MEAN HEIGHT TOP OF CANOPY (meters)	LOWEST BRANCHES (meters)	% CANOPY CLOSURE BY SEASON DEC-FEB	MAR-MAY	JUN-SEP	OCT-DEC
1	60	3	50	75	100	60
2	35	3.5				
4	75	4	5	60	90	60
5	25	5				
6	40	3	20	25	60	30
7	75	4.[illegible]				
8	55	5	5	80	100	40
9	80	3				
10	45	3.5				
11	25	2.5				
12	85	[illegible]				
13	3	1.75				
15	5	[illegible]				
16	8	1.5				
17	35	2.5				
18	5	[illegible]				

TABLE A-1. Vegetation Data Table 1

MAP UNIT IDENTIFICATION	CODE	SPECIES DATA: SPECIES IDENTIFICATION: SCIENTIFIC NAME	ENGLISH NAME	LOCAL NAME	SEASONALITY	% OF STAND	DISTRIBUTION PATTERN	GROUND COVER: TYPE	NAME	MAX % COVER: MONTH	%	MAX HEIGHT: MONTH	HEIGHT (m)	LITTER: TYPE	MAX DEPTH: MONTH	DEPTH (cm)	REPRESENTATIVE TRANSECT
1	a	LIRIODENDRON	YELLOW POPLAR	TULIP	MAY-OCT	50	BROADCAST	SHRUB	LARUEL	JAN-DEC	5	JAN-DEC	2	LEAVES	NOV	25	
		TULIPIFERA		TREE			RANDOM	VINE	VA CREEPER	JUN-OCT	20	JUN-OCT	20				
	b	LIQUIDAMBAR L	SWEET GUM	RED GUM	MAY-OCT	30											
	c	ILEX OPACA	HOLLY	HOLLY	JAN-DEC	10											
2	a	PINUS L	VIRGINIA PINE	PINE	JAN-DEC	40	BROADCAST	SHRUB	POISON IVY	JUNE	40	JUN-OCT	1	LEAVES	NOV	25	
	b	LIRIODENDRON	YELLOW POPLAR	TULIP TREE	APR-OCT	20	CLUSTERS	VINE	HONEYSUCKLE	JUNE	35	JUN-OCT	.5	NEEDLES	JAN-DEC	5	
		TULIPIFERA					BROADCAST	BRAMBLES	BLACKBERRY	JUN-NOV	20	JUL-NOV	1.5				
	c	LIQUIDAMBAR L	SWEET GUM	RED GUM	MAY-OCT	25											
	d	CORNUS L	DOGWOOD		MAY-OCT	10											
3	a	PINUS L	VIRGINIA PINE	PINE	JAN-DEC	75	BROADCAST	BRAMBLES	BLACKBERRY	JUN-NOV	50	JUL-NOV	1.5	NEEDLES	JAN-DEC	5	
	b	FAGUS	BEECH	BEECH	MAY-DEC	10	BROADCAST							LEAVES	NOV	5	

VEGETATION DATA TABLE 2
SPECIES DATA, GROUND COVER, AND LITTER

TABLE A-2. Vegetation Data Table 2

(2) Species Data

(a) Species Code: A single letter alphabetic code will be assigned each species occurring in the primary canopy (2 meters or higher) and recorded in the second column.

(b) Species Identification: It is not essential that each species' scientific, English, and local names be recorded. However, two types of names should be recorded where possible to minimize ambiguity.

(c) Seasonality: The starting and ending months of the period during which the species is in foliage will be recorded in this column. In the case of plants perennially in foliage, January and December will be recorded.

(d) Percent of Stand: The percent of each species occurring in the map unit will be recorded in this column. The percentage will be based on the number of plants. Percentages may not always total 100 percent because of an inability to identify all species.

(e) Distribution Pattern: Distribution of each species within the map unit area will be classified according to one of the following categories and recorded in this column:

Vegetation Distribution Pattern	Definition
RANDOM	Irregularly spaced individual and small groups of plants.
BROADCAST	Irregularly spaced individual plants.
CLUSTERS	Plants in groups, but mechanically independent; plant shape not affected by association.
CLUMPS	Plants in close association, stems independent; plant shape affected by association.
GRIDS	All plants approximately equally distant from nearest neighbor.
HILLS	Plants grouped in mounds of earth with groups spaced regularly.
ROWS	Plants closely spaced in one direction much more widely spaced in another.
STRIPS	Elongated patches of vegetation.

Definition of the distribution patterns will be placed in Section A as in Figures A1 and A2 of the overlay.

(3) Ground Cover

(a) Type: The types of ground cover (plants less than 2 meters high) will be identified by general terms such as shrubs, grasses, vines, and brambles. Scientific terms should be avoided.

(b) Name: The names of the ground cover plants should be either the English or local names, whichever are known.

(c) Maximum Percent Cover: The time period during which the ground cover plants will give the greatest coverage of the ground will be indicated by recording the abbreviations of the first and last months of the period. Estimations of the percent of ground covered will be made to the nearest 10 percent. Because of overlapping by different species, the total percent of cover can exceed 100 percent.

(d) Maximum Height: The time period during which the plants reach their maximum height will be indicated by recording the abbreviations of the first and last months of the period. Estimates of maximum height will be made to the nearest 0.5 meter.

(4) Litter:

(a) The types of ground litter will be indicated by general terms such as leaves, twigs, needles, branches, etc.

(b) Maximum Depth: The period during which the ground litter reaches its greatest depth will be indicated by recording the abbreviations for the first and last months of the period and the maximum depth in centimeters.

(5) Representative Transect

(a) The representative transect will be a carefully prepared, realistic sketch of a cross section of the vegetation within the area. Particular care will be taken to depict the shapes of the crowns and the relative heights accurately.

(b) The treatment of a nonhomogeneous area, such as shown in the transect for map unit 101 (Table A2), will be done only when the area is too small or too narrow to be depicted on the factor map. Normally, this type of an area would be treated as three or more map units.

(c) Plants shown in the transect will be identified by placing the species code from column 2 within the crown area or a special legend located in area B.

APPENDIX B

PROCEDURAL REFERENCES FOR SELECTED DATA ELEMENTS

Number of Stems per Hectare

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Wolff, G., Moglichkeiten und Grenzen der Messinterpretation forstlicher Luftbilder: Archiv Forstwesen, 1966, p. 169-181.

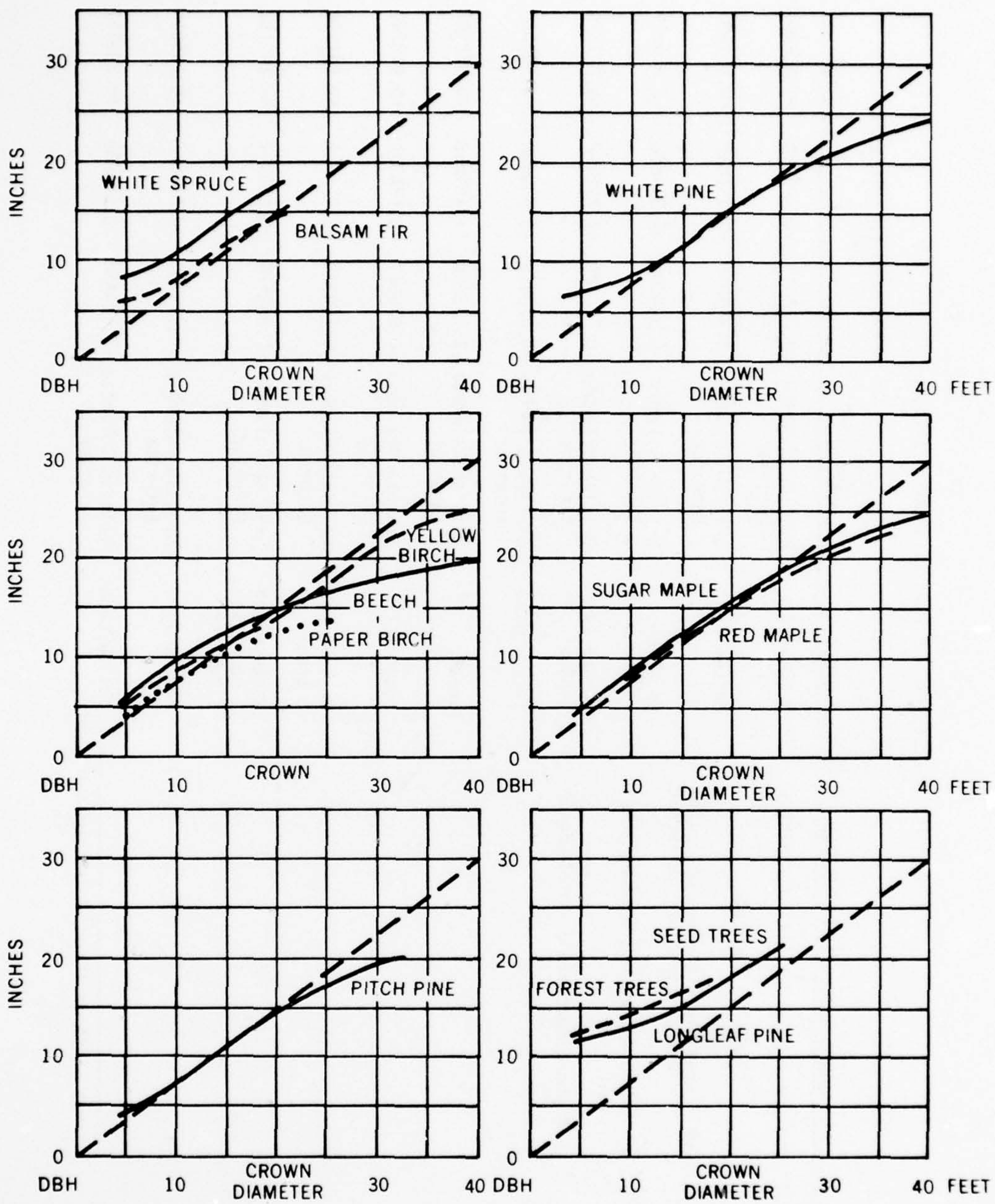

FIGURE B-1. Relationship of Crown Diameter to Stem Diameter for Various American Species[10]

[10] S. H. Spurr, Photogrammetry and Photo-Interpretation, 2nd Edition, The Ronald Press Company, New York, 1960.

TABLE B1. Regression and Rule-of-Thumb Equations

AUTHOR	BASIC REGRESSION EQUATION	SPECIES	LOCATION	REGRESSION COEFFICIENTS b_0	b_1	b_2
Lyons (1967)	$\log dbh = b_0 - 1 + b_1(1 + \log h) + b_2(1 + \log CW)$	Douglas fir	British Columbia Interior	-0.775880	+0.729490	+0.455304
	dbh = tree diameter 4.5 feet above germination point, in inches	Balsam fir	British Columbia Interior	-0.213751	+0.531832	+0.264801
	h = photo determined tree height in feet	Engleman spruce	British Columbia Interior	-0.889605	+0.914648	+0.229799
	CW = photo determined crown width*	Lodgepole pine	British Columbia Interior	-0.725780	+0.812172	+0.223819
		Yellow pine	British Columbia Interior	-0.473410	+0.490698	+0.596072
		Larch	British Columbia Interior	-2.152088	+1.450560	+0.372102
		Douglas fir	British Columbia Exterior	-0.675071	+0.686391	+0.448243
		Western red cedar	British Columbia Exterior	-1.364369	+0.971722	+0.641396
		Western and Mountain hemlock	British Columbia Exterior	-0.639524	+0.809471	+-.260188
		Balsam fir	British Columbia Exterior	-0.771251	+0.858860	+0.265664
		Yellow cedar	British Columbia Exterior	-1.124458	+0.648939	+0.299189

*crown width measured at ½ height in feet

TABLE B1. (Cont.)

AUTHOR	BASIC REGRESSION EQUATION*	FOREST TYPE	LOCATION	REGRESSION COEFFICIENTS a	REGRESSION COEFFICIENTS b
Perez, J.W. (1970)	$D = aS^b$	Lower Montane	V17,20,21,83, 96,133 (See Fig. 34)	0.5442	0.7063
	$S = \sqrt[b]{\frac{D}{a}}$				
	a + b = constants for a specific sample population	Montane	V6,9,10,102 (See Fig. 34)	0.6204	0.6576
	S = stem diameter at breast height (dbh) in centimeters	Monsoon	V340,429,534, 544,657,1001 (See Fig. 36)	0.6341	0.6711
	D = crown diameter in meters	Xerophytic	V18,53,108,109, 125,128 (See Fig. 34)	0.6109	0.7455
		Rainforest palm (Euterpe globosa)	V92,93 (See Fig. 34)	0.6353	0.8392
		Rainforest	V92,93,94,1,2,3 (See Figs. 34&35)	0.5506	0.7194
		Combination of all forest types	Combination of all sites (See Figs. 34-36)	0.5878	0.7011

*This equation is based primarily upon data collected from dicotyledons and therefore is applicable only to such plants.

TABLE B1. (Cont.)

AUTHOR	BASIC REGRESSION EQUATION	SPECIES	LOCATION	REGRESSION COEFFICIENTS a	b_1	b_2	b_3
Bonnor, G.M. (1968)	$D = a + b_1H + b_2W + b_3HW$	Balsam fir	Eastern and Middle Canada	-0.2438	+0.1035	-0.008882	+0.004220
	D = stem diameter at breast height in inches	White pine	Eastern Canada	-0.5347	+0.1122	+0.02514	+0.003660
	H = tre[illegible] et	Jack pine	Eastern and Middle Canada	-0.2974	+0.08382	+0.1834	+0.002197
	W = crown width in feet	White spruce	Eastern and Western Canada NW Territories	+1.706	+0.1264	+0.2009	+0.002284
		Aspen	Eastern Canada	-3.270	+0.1389	+0.3106	-0.009429
		White Birch	Eastern Canada	-2.983	+0.1198	+0.3319	-0.001123
		Yellow Birch	Eastern Canada	-3.881	+0.1618	+0.2814	+0.000198
		Beech	Eastern Canada	-3.333	+0.1545	+0.05224	+0.001619
		Maple	Eastern Canada	-2.550	+0.1344	+0.0830	+0.001919
		Red pine	Eastern Canada	-2.687	+0.06766	+0.5766	+0.000140
		Black spruce	Eastern Canada	+0.247	+0.08023	+0.05529	+0.004292

TABLE B1. (Cont.)

AUTHOR	BASIC REGRESSION EQUATION	SPECIES	LOCATION	REGRESSION COEFFICIENTS b_1	b_2	b_3
Wodera, H. (1948)	$dbh = b_1 + b_2D + b_3D^2$	Spruce	Switzerland Saxony	-33.6	+26.6	-2.5
	dbh = tree diameter at breast height in centimeters	Fir	Switzerland Saxony	-5.2	+6.8	-
	D = photo determined crown diameter in meters	Pine	Switzerland Saxony	-3.5	+8.1	+0.31
		Beech	Switzerland Saxony	-6.4	+8.7	-0.4
Minor, C.O. (1951)	$dbh = b_1 + b_2D$	Loblolly Pine	SE U.S.	+4.66	+0.55	-
	dbh = tree diameter at breast height in inches	Longleaf Pine	SE U.S.	+2.39	+0.62	-
	D = crown diameter in feet					

TABLE B1. (Cont.)

AUTHOR	BASIC REGRESSION EQUATION	SPECIES	LOCATION	REGRESSION COEFFICIENTS a	b
Aldred, A.H. Kippen, F.W. (1967)	$D^2 = -a + b(H \times CA)$ D = stem diameter at breast height in inches H = tree height in feet CA = crown area in feet^2	White pine Red pine	Eastern Canada	-44.63	+0.209
		White birch Maple Ironwood Aspen	Eastern Canada	-13.691	+0.144
Aldred, A.H. Kippen, F.W. (1967)	$D = -a + b(H \times CA)$ D = stem diameter at breast height in inches H = tree height in feet CA = crown area in feet^2	Balsam fir White spruce	Eastern Canada	+1.327	+0.0139

TABLE B1. (Cont.)

AUTHOR	BASIC REGRESSION EQUATION	FOREST TYPE	LOCATION	CHARACTERISTICS	REGRESSION COEFFICIENTS b_1	b_2	b_3
Swellengrebel, E.J. (1959)	$Y = b_1 + b_2(X + b_3)$ Y = bole diameter in inches X = crown diameter in feet	Wallaba Forest	British Guiana	Canopy range: 80-120 feet Crowns more or less in one plane Dominant: *Eperua spp.* (Wallaba) Found on white sand	+3.97	+0.618	-4.67
		Mixed Forest	British Guiana	Canopy range: 70-170 feet Crowns uneven No single dominant Found on brown sand	+5.67	+0.593	-6.30
		Mora Forest	British Guiana	Canopy range: 100-150 feet Crowns larger than those in Wallaba or Mixed Forest Dominant: *Mora excelsa* Found in creek valleys	+5.74	+0.735	-6.31

TABLE B1. (Cont.)

AUTHOR	BASIC REGRESSION EQUATION	SPECIES	LOCATION	REGRESSION COEFFICIENTS a	REGRESSION COEFFICIENTS b
Dawkins, H.C. (1963)	$dbh = (D - a) \left(\frac{1}{b}\right)$	Aucoumea klaineana	Tropics	.9	18
		Aucoumea (extreme density)		1.5	13.5
	dbh = tree diameter at breast height in meters	Byrsonima spicata		.5	23.5
		Dacryodes excela		1.5	16
		Didymopanax morototoni		1.0	22
	D = crown diameter in meters	Dryobalanops aromatica		1.0	19
		Maesopsis eminii		1.0	25
		Manilkara nitida		1.5	17
		Nauclea diderrichii		2.0	16.5
		Ochroma lagopus		.7	20.5
		Ormosia krugii		1.3	20
		Shorea leprosula		1.0	23.5
		Shorea parvifolia		.6	22.3
		Simarouba amara		1.0	18
		Swietenia macrophylla		.4	19
		Terminalia ivorensis		1.2	23
		Terminalia obovata		2.0	20
		Triplochiton scleroxylon		1.4	17

TABLE B1. (Cont.)

AUTHOR	RULE OF THUMB	SPECIES	LIMITATIONS	LOCATION
Smith, H.G. (1965)	dbh = CW dbh = tree diameter at breast height in inches CW = crown width in feet	Major coniferous	Stands of normal density	British Columbia
Smith, H.G. (1965)	dbh = 2CW dbh = tree diameter at breast hieght in inches CW = crown width in feet	Major coniferous	More open stands	British Columbia
Smith, H.G. (1965)	dbh = 0.7CW dbh = tree diameter at breast height in inches CW = crown width in feet	Major coniferous	Very dense stands	British Columbia

TABLE B1. (Cont.)

AUTHOR	RULE OF THUMB	SPECIES	LIMITATIONS	LOCATION
Spurr, S. H. (1960)	dbh = 0.75 D dbh = tree diameter at breast height in inches D = crown diameter in feet	Eastern American	Middle-diameter classes	Eastern U.S.
Spurr, S. H. (1960)	dbh = D dbh = tree diameter at breast height in inches D = crown diameter in feet	Pacific Coast	None given	U.S. Pacific Coast
Paijmans, K. (1951)	$dbh = \frac{D + 4.4}{28.6}$ dbh = tree diameter at breast height in meters D = crown diameter in meters	Many Celebes Species	None given	Indonesia

Table B1. (Cont.)

AUTHOR	RULE OF THUMB	SPECIES	LIMITATIONS	LOCATION
Minor, C.O. (1951)	$dbh = 5 + \frac{D}{2}$ dbh = tree diameter at breast height in inches D = crown diameter in feet	Loblolly, Longleaf, Shortleaf, and Slash pine, Spruce	Stands 30-70 years in age	Southeastern U.S.
Reed, J.C. (1957)	$dbh = \frac{H}{6.5}$ dbh = tree diameter at breast height in inches H = tree height in feet	White spruce, Birch, Cottonwood	None given	Alaska
Heinsdyk, D. (1960)	$dbh = \frac{D + 6}{29}$ dbh = tree diameter at breast height in meters D = crown diameter in meters	Many Amazonian species	None given	Amazon
Macabeo, M. E. (1959)	$dbh = \frac{D + 6.1}{21}$ dbh = tree diameter at breast height in meters D = crown diameter in meters	*Pentacme sp.*	None given	Philippines

Sample Stem Diameter Calculations

Example 1.

Forest type = Lower Montane

Regression equation = $S = \sqrt[b]{\frac{D}{a}}$

Photo-measured crown diameter (D) = 8 meters

Regression coefficients $a = 0.5442$, $b = 0.7063$

$$S = \sqrt[b]{\frac{D}{a}}$$

Procedure	Equation Form	Logarithmic Table Value
1. Convert regression equation to logarithmic form for solving.	$S = \text{antilog}\left(\frac{\log\left(\frac{D}{a}\right)}{b}\right)$	Not applicable
2. Substitute values for D, a, and b into the equation.	$S = \text{antilog}\left(\frac{\log\left(\frac{8}{0.5442}\right)}{0.7063}\right)$	Not applicable
3. Divide D by a.	$\frac{8}{0.5442}$	Not applicable
4. Look up $\log\left(\frac{D}{a}\right)$ in logarithm table.	log(14.7)	1.16732
5. Divide $\log\left(\frac{D}{a}\right)$ by b.	$\frac{1.16732}{0.7063}$	Not applicable
6. Look up antilog of $\frac{\log\left(\frac{D}{a}\right)}{b}$	antilog 1.65273	44.9

Alternate Methods

Example 2: (Same data as Example 1.)

If a calculator with logarithm and inverse function keys is available, the use of logarithm tables is eliminated.

$$S = \sqrt[b]{\frac{D}{a}}$$

Procedure*	Equation Form	Calculator Display
1. Convert regression equation to logarithmic form for solving.	$S = \text{antilog}\left(\frac{\log\left(\frac{D}{a}\right)}{b}\right)$	None
2. Substitute values of D, a, and b into the equation.	$S = \text{antilog}\left(\frac{\log\left(\frac{8}{0.5442}\right)}{0.7063}\right)$	None
3. Divide D by a.	$\frac{8}{0.5442}$	14.7
4. Determine log of $\left(\frac{D}{a}\right)$	log(14.7)	1.16732
(a) press "2nd" key		
(b) press "log" key		
5. Divide log $\left(\frac{D}{a}\right)$ by b.	$\frac{1.16732}{0.7063}$	1.65273
6. Determine antilog of $\log\left(\frac{\frac{D}{a}}{b}\right)$	s = 44.9 cm	44.9
(a) press "2nd" key		
(b) press "INV" key		
(c) press "log" key		

*Procedural steps apply specifically to Texas Instruments SR-52, however, similar steps are applicable to other electronic calculators.

Example 3. (Same data as Example 1.)

The use of logarithms is eliminated if the calculator provides a direct means of determining the x^{th} root of y ($\sqrt[x]{y}$) as shown in the example below.

$$S = \sqrt[b]{\frac{D}{a}}$$

Procedure*	Equation Form	Calculator Display
1. Substitute values of D, a, and b into the equation.	$S = \sqrt[0.7063]{\frac{8}{0.5442}}$	None
2. Divide D by a.	$\frac{8}{0.5442}$	14.7
3. Calculate b^{th} root of $\frac{D}{a}$.	$\sqrt[0.7063]{14.7}$	
(a) press "$\sqrt[x]{y}$" key		
(b) enter value of "b"		
(c) press "=" key	S = 44.9 cm	44.9

*Procedural steps apply specifically to Texas Instruments SR-52, however, similar steps are applicable to other electronic calculators.

APPENDIX C. LOCATION OF SOURCES

C-1. LITERATURE SOURCES

GEOLOGICAL SURVEY LIBRARY

Address: National Center-STOP 950, 12201 Sunrise Valley Drive, Reston, Virginia 22092

Resources: This is a comprehensive working and research library with a book and periodical collection largely devoted to the Survey's main subjects of interest such as: geology, paleontonlogy, mineralogy, petrology, mineral resources, water resources, surveying and cartography, chemistry and physics, oceanography, soil science, zoology, natural history, remote sensing, environmental science, and geothermal energy.

NATIONAL AGRICULTURAL LIBRARY

Address: Route 1, Beltsville, Maryland 20705

Resources: The library's objective is to acquire and permanently retain at least one copy of all substantive publications in the field of agriculture has resulted in a collection which currently numbers about 1.3 million volumes. Most of the holdings are in technical fields such as botany, chemistry, entomology, forestry, food and nutrition, law, water resources and economics.

NATURAL RESOURCES LIBRARY (U.S. DEPARTMENT OF THE INTERIOR)

Address: C Street between 18th and 19th Street, N.W. 20240, STOP 43

Resources: In the library are approximately 775,000 volumes including 4,000 current periodicals and 8,000 other serial titles. The collection is devoted primarily to conservation of natural resources, energy and power, land use and reclamation, parks and outdoor recreation, fish and wildlife, welfare of native races, mines and minerals, and law.

SMITHSONIAN INSTITUTION LIBRARIES-MUSEUM OF NATURAL HISTORY BRANCH

Address: Natural History Building, Room 25, 10th and Constitution Avenue, N.W. 20560, STOP 217

Resources: It has approximately 650,000 volumes and is particularly rich in the literature of systematic biology, anthropology, mineral sciences, zoology, paleobiology, ecology, environmental biology and taxonomy and systematics of arachnids.

C-2. VEGETATION MAPS

Africa, set

Carte de la Vegetation de L'Afrique Tropicale Occidentale

1:1,000,000

4 sheets
1951-1961
Guy Roberty, Office de la Recherche Scientifique et Technique

(notation in French only)

Africa

Carte De La Vegetation De L'Afrique Tropicale Occidentale

1:1,000,000

3 sheets:	ND 28 Dakar	1961
	NC 28 Conakry	1951
	NB 28 Bonthe	1957

Africa, section

Vegetation Map of Africa - South of the Tropic of Cancer

1:10,000,000

1959
Cook, Hammond and Kell, London

33½" x 30½"
(text in French and English. Accompaning text
cataloged in library collection - 581.96/As78)

Alaska

Map of Alaska Showing Vegetation Types

1:5,000,000
1 sheet
1971
Leslie A. Viereck, Forest Service, U.S. Department of Agriculture

Accompanying text - U.S.D.A. Handbook No. 410

Arizona

Arizona Natural Vegetation

1:3,168,000

1963
R.R. Humphrey
University of Arizona. Agricultural Experiment Station and
Cooperative Extension Service.
Tucson, 1963

17" x 22"

Asia, Set

International Map of the Vegetation and of Environmental Conditions

1:1,000,000

14 sheets
1962-1971

(notation in French only on some maps, French and English on others)

International Map of the Vegetation and of Environmental Conditions

1:1,000,000 E-1:1,000,000

7 sheets:	Cape Comorin	Indian Council of Agricultural Res.	nd	Fr & Eng
	Cambodge	Indian Council of Agricultural Res.	1971	French
	Ceylon	Ceylon Survey Dept	1964	Fr & Eng
	Rajasthan	Indian Council of Agricultural Res.	1970	Fr & Eng
	Madras	"	1962	Fr & Eng
	Jagannath	"	1963	Fr & Eng
	Godavari	"	1963	Fr & Eng

International Map of the Vegetation and of Environmental Condition

1:1,000,000 E-1:1,000,000

7 sheets:	Kathiawar	Indian Council of Agricultural Res.	1966	Fr/Eng
	Satpura Mts	"	1966	Fr/Eng
	Mysore	"	1964	Fr/Eng
	Bombay	"	1965	Fr/Eng
	Baie D'Ampasindava (Madagascar-north)	Republique Malgache	1965	French
	Cap St Andre-Lac Alaotra (Madagascar-middle)	"	1965	French
	Mangoky-Cap Ste Marie (Madagascar-south)	"	1965	French

Asia, section

Vegetation of Central Asia

1:1,000,000

1970
Army Engineer Topographic Laboratories
Ft. Belvoir, VA

14" x 20"
(corresponds to technical report 71-19-ES,
USA NLabs, Dec. 1970)

Southeast Asia

Vegetation Types

1969

Niedringhaus, T.E., In Mainland Southeast Asia, A Folio of Thematic Maps for Military Users

Tech. Rept. 70-21-ES, U.S. Army Natick Labs, Natick, Mass.

Australia

Vegetation Map of Australia

1960

Williams, R.J.

Accompanying text - The Australian Environment (3rd ed.), CSIRO, Cambridge University Press, London & New York

Austria, set

Karte der Aktuellen Vegetation Tirols

1:100,000   E-1:100,000

2 sheets
1969-1971
Freytag-Berndt

Notation in German only

Karte Der Aktuellen Vegetation Tirols

1:100,000   E-1:100,000

2 sheets:	Blatt 6	Innsbruck-Stubaier Alpen	1969
	Blatt 7	Zillertaler und Tuxer Alpen	1970

Bechuanaland, set

Land Systems of Eastern Bechuanaland

1:500,000

3 sheets
1963
Directorate of Overseas Surveys

Land Systems of Eastern Bechuanaland

1:500,000

3 sheets:	Sheet 5	1963
	Sheet 8	1963
	Sheet 11	1963

Belgium, set

Carte de la Vegetation de la Belgique

1:20,000

2 sheets
1956-1960
L'Institute Pour L'Encouragement de la Recherche
Scientifique dans L'Industrie et L'Agriculture

Notation in French and German

Carte de la Vegetation de la Belgique

1:20,000

2 sheets:	123W	Henri-Chapelle	1956
	195E	Saint Hubert	1960

Brazil, section

Phytogeographical Map of the State of Parana

1:750,000

1950
Reinhard Maack
Instituto de Biologia e Pesquisas Technologicas

48" x 35"
(notation in Spanish)

British Columbia

Biogeoclimatic Zones of British Columbia

1:1,900,800

no date
V.J. Krajina
Department of Lands, Forest, and Water Resources, British Columbia

37" x 30"

Canada

Forest Classification of Canada and Coast of Labrador

1:6,336,000

1937
Department of Mines and Resources. Lands, Parks and
Forest Branch. Dominion Forest Service, Ottawa

25" x 36"

Corsica, section

Groupements Vegetaux Terrestres-Biocenoses et Biotopes Marins

1:80,000

1963
Roger Molinier, Centre National de la Recherche Scientifique
Service de la Carte des Groupements Vegetauz, Montpellier

27" x 41"
(schematic Map.. notation in French only)

Columbia

Mapa Ecologico de Colombia

1:1,000,000

1963
Espinal et al Instituto Geografico "Augustin Codazzi".
Bogota

Accompaning text - Formaciones vegetales de Colombia.
Describes many of the life zones, their vegetation and prevalent land use patterns.

Costa Rica

Republica de Costa Rica, Mapa Ecologico

1:750,000

1969
Tosi, J.A., Tropical Science Center, San Jose, Costa Rica

Life zones mapped are Holdridge's bioclimatic units, each of which may represent a variety of soils, veg., microclimates and land use patterns.

Dominican Republic

Mapa Ecologico de la Republica Dominicana

1:250,000

1967
Tasaico, H., Pan American Union, Washington, D.C.

Accompanying text - Reconocimiento y evaluacion de los recursos naturales de la Republica Dominicana: estudio para su desarrollo y planificacion. Describes many of the life zones, their vegetation and prevalent land use patterns.

Ecuador

Croquis Ecologico Parcial del Ecuador

1:1,000,000

Vivanco de la Torre, O., et al IERAC. Quito, Ecuador

Accompanied by monographs containing descriptions of many of the life zones, their vegetation and prevalent land use patterns.

El Salvador

Mapa Ecologico de El Salvador

1:1,000,000

1959
Holdridge, L.R., Interamerican Institute of Agricultural Science, Turrialba, Costa Rica

Life zones mapped are Holdridge's bioclimatic units, each of which may represent a variety of soils, vegetation, microclimates and land use patterns.

Europe, section

Vegetation-Zonen Sudosteuropas

1:2,000,000

1972
Gustav Fischer Verlag, Stuttgart

27" x 38"
(notation in German only)

Southern Europe

Vegetations Karte von Sudosteuropa

1972

Gustav Fischer Verlag, Stuttgart.

Florida

General Map of Natural Vegetation of Florida

1:10,700

1967 Agricultural Experiment Stations, Gainesville

29" x 25"

France, set

Carte de la Vegetation de la France

1:200,000

4 sheets
1970-1971
P. Ozenda
Le Centre National de la Recherche Scientifique

notation in French

Carte de la Vegetation de la France

1:200,000

9 sheets:	Digne	1970
	Lille	1970
	Clermont-Ferrand	1971
	Cherbourg	1971
	Montpellier	1966
	Paris	1966
	Nantes	1965
	Rouen	1964
	Gap	1964

Carte de la Vegetation de la France

1:200,000

2 sheets:	Corse	1965
	Bordeaux	1962

Guatemala

Mapa Ecologico de Guatemala

1:1,000,000

1959

Holdridge, L.R., A.C. Interamerican Institute of Agricultural Science, Turrialba, Costa Rica

Life zones mapped are Holdridge's bioclimatic units, each of which may represent a variety of soils, vegetation, microclimates and land use patterns.

Haiti

Ecologie. Republique D'Haiti

1:500,000

1972

Organization of American States, Washington, DC

Life zones mapped are Holdridge's bioclimatic units, each of which may represent a variety of soils, vegetation, microclimates and land use patterns.

Honduras

Mapa Ecologico de Honduras

1:1,000,000

1962

Holdridge, L.R., Organization of American States, Washington, DC

Life zones mapped are Holdridge's bioclimatic units, each of which may represent a variety of soils, vegetation, microclimates and land use patterns.

Humid Tropical Environments

Vegetation Maps

1968

Sands, R.D., In Humid Tropical Environment - A Militarily Significant Classification. University of Denver, Denver, CO

Contract DA19-129-AMC-891(N), U.S. Army Natick Labs, Natick, Mass.

Ivory Coast, section

Carte de la Vegetation de la Region de Bereby

1:50,000

1962

Office de la Recherche Scientifique et Technique outre-Mer, A. Perraud

22-1/2" x 42-1/2"
(Notation in French)

Jamaica

Forest Inventory Map No. 3, Life zones

1:500,000

1969

Gray, K.M. & Symes, G.A., U.N.D.P. Forestry/Watershed Management Project - Kingston, Jamaica

Life zones mapped are Holdridge's bioclimatic units, each of which may represent a variety of soils, vegetation, microclimates and land use patterns.

Japan

Actual Vegetation

1:2,500,000

1977

The National Atlas of Japan, The Japan Map Center,
Tokyo, Japan

Kenya, set

Vegetation-Land Use Survey

1:250,000

2 sheets
1966-1969

British Government's Ministry of Overseas Development, Kenya

Vegetation-Land Use Survey

1:250,000

2 sheets:	Sheet 1	1966
	Sheet 3	1969

Pacific Islands, section·
Malaysia

Vegetation Map of Malaysia

1:5,000,000

1958

C. G. G. J. van Steenis, UNESCO

28" x 50"
(explanatory text is attached)

Mediterranean Area

Vegetation Map of the Mediterranean Zone

1969

UNESCO, Paris

With explanatory notes.

Mediterranean, set

Vegetation Map of the Mediterranean Region

1:5,000,000

2 sheets

1968

FAO-UNESCO, Paris

Notation in French and English

Vegetation Map of the Mediterranean

1:5,000,000

2 sheets:	East Sheet	1968
	West Sheet	1968

Maryland, section
Indian Head

Indian Head-Experimental Edition-1

1:50,000

1956

Army Engineer Topographic Laboratories, Ft. Belvoir, VA

Transverse Mercator Projection
22-1/2" x 29"
(enrichment information has been added by ETL)

Vegetation Map of the Mediterranean Region

1:5,000,000

2 sheets: East sheet 1968
West sheet 1968

Netherlands, set

Het Savelsbos. Bosgezelschappen en bodems

1:5,000

2 sheets
1966
Stichting Voor Bodemkartering, Wageningen

Notation in Dutch and French

HET SAVELSBOS. BOSGEZELSCHAPPEN EN BODEMS

1:5,000

2 sheets:	Bijlage 2.	Bodemkaart van het Savelsbos	1966
	Bijlage 1.	Plantensociologische Kaart van het Savelsbos	1966

Nicaragua

Mapa Ecologico de Nicaragua

1:1,000,000

1962

Holdridge, L. R., A. C. United States Agency for International Development, Managua, Nicaragua

Life zones mapped are Holdrige's bioclimatic units, each of which may represent a variety of soils, vegetation, microclimates and land use patterns.

Nigeria

Provisional Ecological Map of Nigeria

1:3,000,000

1968

Tosi, J.A., Tropical Science Center, San Jose, Costa Rica

Life zones mapped are Holdridge's bioclimatic units, each of which may represent a variety of soils, vegetation, microclimates and land use patterns.

Ohio

Original Vegetation of Ohio at the time of the Earliest land Surveys

1:2,000,000

no date

Ohio Biological Survey

Oklahoma

A Game Type Map of Oklahoma

no scale indicated

1943

Division of Wildfile Restoration

8-1/2" x 11" (additional notes on back of map)

Panama

Panama. Zonas de Vida

1:500,000

1971
FAO Informe tecnico 2. FO:SF/PAN 6.
Rome, Italy

Accompanying text-Inventariacion y demostraciones forestales, Panama. Zonas de Vida. Describes many of the life zones, their vegetation and prevalent land use patterns.

Peru

Zonas de vida natural en el Peru

1:1,000,000

1960

Tosi, J.A., Instituto Interamericano de Ciencias
Agricolas de la O.E.A., Zona Andina, Lima

Accompanying text-Zonas de vida natural en el Peru:
Memoria explicativa sobre el mapa ecologico de Peru.
Boletin Tecnico, No. 5. Describes many of the life zones,
their vegetation and prevalent land use patterns.

Puerto Rico

Ecological Life Zones of Puerto Rico and the United States
Virgin Islands

1:250,000

1 sheet

1973

U.S.D.A. Forest Service, Institute of Tropical
Forestry Rio Piedras, Puerto Rico

Accompanying text - Forest Service Research Paper ITF-18

Senegal, section
Thies

Carte de la Vegetation de L'Afrique Occidentale
Francaise

1:200,000

1950

L'Office de la Recherche Scientifique Outre-Mer
Paris

29" x 31"
(Notation in French only)

Sudan

Vegetation of Sudan

1:4,000,000

1967

Sudan Survey Department, Khartoum

23" x 36"

Sudan

Ecological Map Showing Major Vegetation and
Grazing Zones of Sudan

1:8,000,000

1958

Sudan Survey Department, Khartoum

18" x 11-1/2"
(Indicates suggested locations of grassland
experimental centers)

Tanganyika

A Vegetation - Types Map of Tanganyika Territory

1949

Gillman, C., Geographical Review, V. 39, pp. 7-37.

Thailand (seven sites)

4 sheets:	No. 1	1965	1:500,000
	No. 2	1965	1:500,000
	Ecological & land use characteristics west of Chaing Mai, Thailand	1965	1:15,000-1:25,000
	Republica de Costa Rica Mapa Ecologico	1969	1:750,000

Holdridge et al. 1971, Pergamon Press, Oxford, 747 p.

Accompanying text - Forest environments in tropical life zones, a pilot study. Describes many of the life zones, their vegetation and prevalent land use patterns.

Thailand

Map of Thailand showing Types of Forest

1:2,500,000

1 sheet
1967
Environmental Sciences Division, Royal Thai Military
Research and Development Center

notation in English

Karte der Aktuellen Vegetation Tirols

1:100,000

2 sheets:	Blatt 6	Innsbruck-Stubaier Alpen	1969
	Blatt 7	Zillertaler und Tuxer Alpen	1970

Uganda, set

Uganda Vegetation

1:500,000

4 sheets
1964
Department of Lands and Surveys, Uganda

(all 4 sheets interconnect to form one large map)

Uganda Vegetation

1:500,000

4 sheets:	Sheet 1	1964
	Sheet 2	1964
	Sheet 3	1964
	Sheet 4	1964

Uganda

Uganda Vegetation

1:1,500,000

1962

Department of Lands and Surveys, Uganda

21" x 21"

(additional information and pictures on back)

Union of S.S.R.

U.S.S.R. Vegetation Zones

1:25,000,000

no date
Department of State. Division of Geography and Cartography, Washington, DC

16-1/2" x 11"
(adapted from Bol'shoy Sovetskly Atlas Mira,
1, pl. 121-122)

United States

Potential Natural Vegetation of the Conterminous United States

1:3,168,000

1964
American Geographical Society, New York

39" x 60"

United States

Major Forest Types

1:1,000,000

8 sheets
1934-1941
Department of Agriculture. Forest Service
Southern Forest Experiment Station

Eastern North America

Map of Deciduous Forest Regions and Sections

1:5,500,000 (approx)

1 sheet
1950

Hafner Publishing Company, Inc., NY, NY 10003

Accompanying text - Deciduous Forest of Eastern North America

United States, East of the Rockies

The Holdridge Bioclimatic Formations of the Eastern & Central United States

1:26,800,000

1964

Sawyer, JO and A.A. Lindsey, Proc. Indiana Acad. Sci. 73: 105-112.

Life zones mapped are Holdridge's bioclimatic units, each of which may represent a variety of soils, vegetation, microclimates and land use patterns.

Major Forest Types

1:1,000,000

8 sheets:	Mississippi	1934
	Virginia	1941
	Alabama	1934
	Arkansas	1936
	Louisiana	1934
	South Carolina	1940
	Georgia	1934
	Florida	1934

Venezuela

Mapa Ecologico de Venezuela

1:2,000,000

1968

Ewel, J. et al. Ministerio de Agriculture y Cria.
Direccion de Investigacion. Caracas

Accompanying text - Zonas de vida de Venezuela. Describes many of the life zones, their vegetation and prevalent land use patterns.

Viet Nam, set

Viet Nam

1:500,000

12 sheets

1961-1964

National Geographic Service of Viet Nam

(notation in Vietnamese, French, and English)

Viet Nam

1:500,000

12 sheets:	1	Son Tay	1964
	2	Ha Noi	1964
	3	Vinh	1964
	4	Hai Phong	1964
	5	Vientiane	1961
	6	Hue	1963
	7	Pakse	1961
	8	Qui Nhon	1963
	9	Phnom Penh	1961
	10	Dalat	1963
	11	Can Tho	1964
	12	Saigon	1964

Viet Nam

Vegetation Map of Viet Nam Republic

1:1,000,000

1969
National Geographic Service, Dalat

28-1/2" x 41"
(notation in Vietnamese and English.
plantations and rice fields are also indicated)

World

Goodes World Atlas

Various scales

1966
Rand McNally & Company, Chicago

Vegetation Maps of the world

World

Coastal Vegetation of the World

1960

Axelrod, D.I.

Accompanying text - Natural Coastal Environment of the World,
W.C. Putnam et al, Univ. of California, L.A.
(ONR Contract)

C-3. AERIAL IMAGERY SOURCES

U.S. GOVERNMENT AGENCIES

Aerial Photography Field Office

Agricultural Stabilization and Conservation Service
Department of Agriculture
Western Laboratory
2505 Parleys Way
Salt Lake City, Utah 84109 (Source for all states)

Defense Intelligence Agency
ATTN: DIAAP-10
Washington, D. C. 20315

World wide survey photography held by DMAHC
6500 Brooks Lane
Washington, D.C. 20335

Bureau of Land Management
Department of Interior
Washington, D.C. 20240

Cartographic Archives Division
National Archives (GSA)
Washington, D.C. 20408

EROS Data Center
U.S. Geological Survey
Sioux Falls, South Dakota 57198

National Cartographic Information Center (Headquarters)
Geological Survey
Department of Interior
Reston, VA 22090

NCIC-Mid-Continent
USGS, 1400 Independence Rd.
Rolla, Missouri 65401

NCIC-Rocky Mountain
USGS, Topographic Division
Stop 510, Box 25046
Denver Federal Center
Denver, Colorado 80225

NCIC-Western
USGS, 345 Middlefield Rd.
Menlo Park, California 94025

National Ocean Survey
Department of Commerce
Washington Science Center
Rockville, Maryland 20852

Soil Conservation Service
Department of Agriculture
Federal Center Building
East-West Highway and Belcrest Rd.
Hyattsville, Maryland 20781

Tennessee Valley Authority
Maps and Surveys Branch
210 Haney Building
Chattanooga, Tennessee 37401

EASTERN US FOREST SERVICE PHOTOGRAPHY

Chief Forest Service
U.S. Department of Agriculture
Washington, D.C. 20250

WESTERN U.S. FOREST SERVICE PHOTOGRAPHY

Region	
1	Federal Building, Missoula, MT 59801
2	Federal Center, Building 85, Denver, CO 80025
3	Federal Building, 517 Gold Ave. SW, Albuquerque, NM 87101
4	Forest Service Building, Ogden, UT 84403
5	630 Sansome St., San Francisco, CA 94111
6	P.O. Box 8623, Portland, OR 97208
10	Regional Forester, U.S. Forest Service, P.O. Box 1628, Juneau, AK 99801

Technology Application Center
The University of New Mexico, Code 11
Albuquerque, New Mexico 87131

STATE AGENCIES

Arizona Highway Department
Adminstrative Services Division
206 South 17th Avenue
Phoenix, Arixona 85007

State of Arkansas Highway Department
Surveys, 9500 New Denton Highway
P.O. Box 2261, Little Rock, Arkansas

State of Nebraska
Department of Roads
14th & Burnham Streets
Lincoln, Nebraska 68502

State of Ohio
Department of Highways
Columbus, Ohio 43216

Oregon State Highway Division
Salem, Oregon 97310

Virginia Department of Highways
Location and Design Engineer
1401 East Broad Street
Richmond, Virginia 23219

State of Washington
Department of Natural Resources
600 North Capitol Way
Olympia, Washington 98501

Southeast Michigan
Council of Governments
1249 Washington Boulevard
Detroit, Michigan 48226

Illinois Department of Transportation
2300 South - 31st Street
Springfield, Illinois 62734

Southeastern Wisconsin Regional Planning Commission
916 North East Avenue
Waukesha, Wisconsin 53186

Wisconsin Department of Transportation
Engineering Services
4802 Sheboygan Avenue
Madison, Wisconsin 53702

Indiana Highway Department
608 State Office Building
Indianapolis, Indiana 46204

COMMERCIAL FIRMS

Aerial Data Service
10338 East 21st Street
Tulsa, Oklahoma 74129

Aero Service Corporation
4219 Van Kirk Street
Philadelphia, Pennsylvania 19135

Air Photographics Inc.
P.O. Box 786
Purcellville, Virginia 23132

Alster and Associates, Inc.
6135 Kansas Avenue, NE
Washington, D. C. 20011

Ammann International Base Map & Air Photo Library
223 Tenth Street
San Antonio, Texas 78215

Burlington Northern Inc.
650 Central Building
Seattle, Washington 98104

Cartwright Aerial Surveys Inc.
Executive Airport
6151 Freeport Boulevard
Sacramento, California 95822

H. G. Chickering, Jr.
Consulting Photogrammetrist, Inc.
P.O. Box 2767
1190 West 7th Avenue
Eugene, Oregon 97402

Fairchild Aeromaps Inc.
14437 North 73rd Street
Scottsdale, Arizona 85254

Grumman Ecosystems Corp.
Bethpage, New York 11714

Henderson Aerial Surveys Inc.
5125 West Broad Street
Columbus, Ohio 43228

Walker and Associates Inc.
310 Prefontaine Building
Seattle, Washington 98104

Western Aerial Contractors, Inc.
Mahlon Sweet Airport - Route 1, Box 740
Eugene, Oregon 97401

L. Robert Kimball
615 West Highland Avenue
Ebensburg, Pennsylvania 15931

Lockwood, Kessler & Bartlett, Inc.
One Aerial Way
Syosset, New York 11791

Mark Hurd Aerial Surveys, Inc.
345 Pennsylvania Avenue South
Minneapolis, Minnesota 55426

Merrick and Company
Consulting Engineers
2700 West Evans
Denver, Colorado 80219

Murry - McCormick
Aerial Surveys Inc.
6220 24th Street
Sacramento, California 95822

Photogrpahic Interpretation Corporation
Box 868, Hanover, New Hampshire 03755

Quinn and Associates
460 Caredean Drive
Horsham, Pennsylvania 13044

Sanborn Map Company, Inc.
P.O. Box 61
629 Fifth Avenue
Pelham, New York 10803

The Sidwell Company
Sidwell Park
28W240 North Avenue
West Chicago, Illinois 60185

Surdex Corporation
25 Mercury Boulevard
Chesterfield, Missouri 63017

Teledyne Geotronics
725 East Third Street
Long Beach, California 90812

United Aerial Mapping
5411 Jackwood Drive
San Antonio, Texas 78238

CANADA

National Air Photo Library
Surveys and Mapping Building
615 Booth St.
Ottawa, Canada K1A OE 9

C-4. GROUND IMAGERY SOURCES

U.S. Army Imagery Interpretation Group
Bldg. 213, Washington Navy Yard
Washington, D.C.

Defense Intelligence Agency
ATTN: RPP-3
Washington, D.C. 20301

U.S. Army DARCOM Service Support Activity
Audio-Visual Presentations Division
Room 1C13, Pentagon
Washington, D.C.

APPENDIX D. REFERENCES

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D-2. SUPPLEMENTARY REFERENCES

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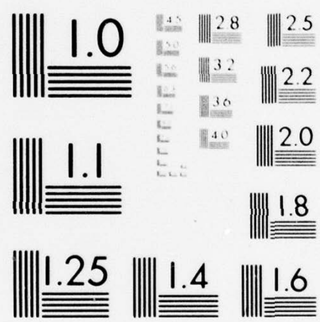

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APPENDIX E.

GLOSSARY

ARBOREAL	Consisting of, or pertaining to, trees. (Ref. 23)
AIR BASE	The line joining two aerial camera stations. (Ref. 3)
ALL-AGED	Applied to a stand of trees in which trees of all ages up to and including those of felling age are found. (Ref. 25)
ALPINE	That region which is above the montane timberline; characterized by the presence of herbs and grass-like plants and low, slow-growing shrubs. (Ref. 30)
ALTITUDE	Height above a datum. The datum is usually mean sea level. (Ref. 3)
ANGIOSPERM	Characterized by having seeds enclosed in an ovary; a flowering plant.
ANNUAL	A plant that lives through its entire life cycle (germinating, flowering, forming seed, and dying) in a single year. (Ref. 23)
AQUATIC	Adapted to submerged or partially submerged habitats. (Ref. 23)
ARBORESCENT	Tree-like. (The term is applied to such unusual growth forms as the Joshua tree and saquaro or giant cactus.) (Ref. 23)
ARCTIC	Of, or characteristic of the region around the north pole to approximately 65^{o} north latitude; all regions north of the boreal timber line. (Ref. 30)
ARID	Without moisture: excessively dry; parched and barren; having insufficient rainfall to support agriculture, usually less than 10 to 15 in. annually. (Ref. 9)
BADLANDS	A region nearly devoid of vegetation where erosion, instead of carving hills and valleys of the ordinary type, has cut the land into an intricate maze of narrow ravines and sharp crests and pinnacles. This extremely rough topography is formed in an advanced stage of gullying in poorly consolidated sediments and is characterized by sharp-edge ridges separated by narrow and steep gullies. Travel across such a region is almost impossible. (Ref. 9)

BARRENS — A relatively desolate area, where vegetation either is lacking (as in an ice cap or desert) or is scanty and restricted to a few species, as compared with adjacent areas, because of adverse soil, wind, or other environmental factors. (Ref. 20)

BASE, EYE — The distance between the eyes. (Ref. 32)

BASE, PHOTO — The line joining two principal points of two consecutive aerial photographs. (Ref. 32)

BIOME — Any of the major terrestrial ecosystems of the world, i.e., tundra, deciduous forest, desert, taiga, etc. (Ref. 30)

BOG — 1. A quagmire or morass; an area of wet, highly acid, peaty, spongy ground, usually lacking in mineral nutrients, often interspersed with pools of open water, where any dense body is likely to sink. (Ref. 5)

2. Botany. The vegetation of saturated, peaty land in open or forest areas; hence moss bog, juncus bog, carex or sedge bog, sphagnum bog, birch bog, tamarack bog, black spruce bog. (Ref. 5)

BOLE — The stem or trunk of a tree, usually the lower, usable or salable portion of the tree trunk. (Ref. 20)

BOREAL FOREST — The forested region that adjoins the tundra along the arctic tree line. It has two main divisions: Its northern portion is a belt of taiga or boreal woodland; its southern portion is a belt of true forest, mainly conifers but with some hardwoods. On its southern boundary the boreal forest passes into "mixed forest" or "parkland", prairie, or steppe, depending on rainfall. (Ref. 18)

BROADLEAF — Generally, one of the botanical group of trees that have broad leaves in contrast to the conifers; also referred to as hardwoods. (Ref. 25)

BRUSH — Shrubs and stands of short, scrubby tree species that do not reach sufficient size for use as timber. (Ref. 25)

BUTTRESS — Planklike outgrowth at the base of a tree trunk. (Ref. 10)

CAATINGA — The dry, open thorn forest of eastern Brazil. (Ref. 23)

CANOPY	A more or less continuous layer of tree crowns of approximately even height. (Ref.)
CANOPY (PRIMARY)	Uppermost closed surface or roof of the forest.
CHAPARRAL	The low, dense scrub vegetation with predominantly evergreen, sclerophyllous leaves, typical of semiarid parts of California. It is similar in structure, but not botanically, to the vegetation of other regions with a "Mediterranean" type of climate (dry summers and rainy winters) such as the maquis of southern France and the mallee of South Australia. (Ref. 23)
CLIMAX VEGETATION	The stable vegetation assumed to be the end result of plant "succession," which develops after a long period without external disturbance. (The climax concept is theoretical and is subject to a variety of interpretations, some authorities rejecting it altogether. (Ref. 23)
CONIFER	A tree or shrub belonging to the order Coniferales. Most conifers are needleleaf plants, but some have scalelike leaves ranging from small, as in many junipers and cedars, to more than an inch wide, as in the monkeypuzzle tree. Most species of conifers are evergreen, but the larches, and some others, are deciduous. (Ref. 20)
CONIFEROUS FOREST	A forest of evergreen coniferous or cone-bearing trees carrying needle-shaped leaves. From such forests is obtained the valuable soft-wood timber of commerce. (Ref. 9)
CONTRAST	The difference in light intensity between the brightest highlights and the deepest shadow. (Ref. 3)
COVER, FOREST	All trees and other woody plants in a forest. (Ref. 25)
CROWN	The upper part of a tree, including the branches with their foliage. (Ref. 20)
DATUM	A reference element, such as a line or plane, in relation to which the positions of other elements are determined. Also called the "reference plane" or "datum plane." (Ref. 3)

DECIDUOUS FOREST — A forest consisting of trees that lose their leaves at some season of the year. In the case of the monsoon forests, such as those of India and Burma, the trees shed their leaves during the hot season in order to protect themselves against excessive loss of moisture by evaporation. Much of the valuable hardwood timber of commerce is obtained from deciduous forests. The deciduous forests of the temperate zones lose their leaves at the onset of the cold season. (Ref. 2)

DENDROLOGY — Botanical study of trees encompassing their description. classification and geographic distribution.

DENSITY, STAND — Density of stocking expressed in number of trees per hectare. (Ref.)

DESERT CLIMATE — The single outstanding characteristic of desert climate is aridity. By most classification systems, areas with an annual rainfall of less than 10 in. are considered desert. Areas considered as deserts are also characterized by clear atmospheres and high solar radiation. (Ref. 9)

DIAMETER, BREAST HIGH — The diameter of a tree at 1.4m (4.5 ft) above average ground level, except that in National Forest practice it is measured from the highest ground level. Abbreviated d.b.h. The additional abbreviations, o.b. and i.b. are used to designate whether the diameter refers to the measurement outside or inside the bark. (Ref. 25)

DICOTYLEDON — Characterized by its seeds having two cotyledons (seed leaves), its floral parts mostly in fives, and its leaves with a characteristic net arrangement of veins. (Ref. 19)

DOMINANT — A species that is so conspicuous in a formation that it gives the formation its characteristic aspect even though other species may be present. (Ref. 23)

DUFF — Forest litter and other organic debris in various stages of decomposition, on top of the mineral soil, typical of conifer forests in cool climates where rate of decomposition is slow, and where litter accumulation exceeds decay. (Ref. 25)

ECOLOGY — The study of the complex interrelations between organisms and their environments. (Ref. 10)

ECOSYSTEM — The interacting system comprising living things, together with their nonliving habitat. (Ref. 10)

EDAPHIC — Relating of or determined by conditions in the soil, rather than by climatic factors. (Ref. 27)

ENDEMIC — Indigenous or native in a restricted locality; confined naturally to a certain limited area or region. (Ref. 30)

EQUATORIAL FOREST or TROPICAL RAIN FOREST — The hot, wet, evergreen forest of the equatorial region, where rainfall is very heavy and where there is no dry season; it extends in parts into monsoon areas. Because of the extreme heat and moisture, the growth is dense and luxuriant. (Ref. 9)

EVEN-AGED — Applied to a stand in which relatively small age difference exist between individual trees. The maximum difference in age permitted in an even-aged stand is usually 10 to 20 years, though where the stand will not be harvested until it is 100 to 200 years old, larger differences up to 25 percent of the rotation age may be allowed. (Ref. 25)

EVERGREEN — Retaining green foliage throughout the year. (Used as both a noun and adjective.) (Ref. 23)

FIDUCIAL MARKS — Index marks, rigidly connected with the camera lens through the camera body, which form images on the negative. The marks are adjusted so that the intersection of lines drawn between opposite fiducial marks defines the principal point. (Ref. 3)

FLORA — 1. The vegetation of a region, zone, or environment.

2. A list, catalogue, or systematic report with keys or descriptions pertaining to the plants of a specific region; hence alpine flora, bog flora. (Ref. 5)

FOCAL PLANE — The plane(perpendicular to the axis of the lens) in which images of points in the object field of the lens are focused. (Ref. 3)

FORB — A broadleaved, herbaceous plant. (Ref. 23)

FOREST PARK — An open stand of trees with grasses underneath rather than the underbrush characteristically associated with forests. (Ref. 25)

FORWARD OVERLAP — See Overlap. (Ref. 32)

GALLERY FOREST (GALLERIA)	A narrow forest extending into grassland, savanna, etc., along watercourses; a fringing forest. (Ref. 10)
GRAMINOID	Grass-like. (In this study the term includes all members of the grass family except the woody bamboos, and other grasslike plants such as sedges.) (Ref. 23)
GRASSLANDS	The regions of the world where the natural vegetation consists of grass; the rainfall is too light to permit forest growth but is less scanty and irregular than that of the deserts; the grasslands are thus normally situated between the forest belts and the arid regions. (Ref. 9)
GROUND COVER	Vegetation (less than 2m high) used to reduce wind and water erosion; include shrubs, grasses, vines, etc. (Ref. 30)
GYMNOSPERM	A class of plants that produces seeds without protective covering; e.g., the conifers. (Ref. 9)
HALOPHYTE	A plant that grows in saline soil.
HARDWOOD	See Broadleaf (Ref. 25)
HEATH	1. A tract of open wasteland covered by low shrubs. 2. Plants and shrubs that grow on heaths; especially, an evergreen subshrub of either of two genera having whorls of needlelike leaves and clusters of small flowers. (Ref. 9)
HERBACEOUS	Any plant lacking woody tissues in which the leaves and stem fall to ground level during freezing or drying weather. (Ref. 30)
HUMID TROPICS	Areas in which the average temperature of the coldest month is about 64.4°F and the annual rainfall rate exceeds the annual evaporation rate. These lands are characterized by rainforest, jungle, and savanna vegetation. (Ref. 12)
HYDRIC	Characterized or pertaining to conditions of abundant moisture supply. (Ref. 30)
HYDROPHYTE	A plant that typically grows in water or in saturated soil. Hydrophytes may be rooted or free floating, submerged, with floating leaves, or with leaves emergent above the water level. (Ref. 20)
IMAGE	The representation of an object produced by optical or chemical means, or both. (Ref. 3)

INVERTED STEREO	See Pseudoscopic stereo. (Ref. 32)
JUNGLE	A dense, tangled second-growth vegetation of grasses, shrubs, small trees, and vines; generally associated with equatorial areas. The term is often used improperly as a synonym for tropical rainforest, which is relatively clear of undergrowth. (Ref. 20)
KRUMMHOLZ	Low, shrubby vegetation with stiff branches, found at mountain tree lines. (Ref. 23)
LATERAL OVERLAP	See Overlap (Ref. 32)
LIANA	A climbing vine. (Ref. 10)
LICHEN	A primitive type of plant having a compound structure consisting of an alga and a fungus. Certain lichens in polar regions are an important source of food for grazing animals. (Ref. 23)
LINE, FLIGHT	A line drawn on a map or chart to represent the track over which an aircraft has been flown or is to fly. The line connecting the principal points of vertical aerial photographs. (Ref. 3)
LITTER	Comprises the upper portion of the forest floor, slightly or not at all decomposed.
MALLEE	A formation of sclerophyllous shrubs (Eucalyptus spp.) in Australia. (Ref. 23)
MANGROVE	One of a group of halophytic evergreen broadleaf trees and shrubs of tropical and subtropical coasts, typically growing in muddy areas, such as lagoons and estuaries, that are submerged perennially or at high tide by brackish or salty water. Many species of mangrove have prop roots or root knees above the ground. (Ref. 23)
MAP, TOPOGRAPHIC	A map showing correct horizontal and vertical positions of features represented. (Ref. 6)
MARSH	A treeless area where the land is usually wet and poorly drained. They may be coastal (salt marsh) or inland (bog, fen). (Ref. 23)
MEADOW	A low, level tract of grassland usually near a lake or stream. (Ref. 9)

MONOCOTYLEDON — Characterized by its seeds having a single cotyledon (seed leaf), its leaves for the most part having parallel veins, and the flower parts normally in threes or multiples of three; represented by the palms, grasses, and sedges. (Ref. 19)

MONSOON — A name for seasonal winds (derived from Arabic mausim, a season). It was first applied to the winds over the Arabian Sea, which blow for 6 mo from northeast and for 6 mo from southwest, but it has been extended to similar winds in other parts of the world. The primary cause is the much greater annual variation of temperature over large land areas compared with neighboring ocean surfaces, causing an excess of pressure over the continents in winter and a deficit in summer, but other factors such as the relief features of the land have a considerable effect. In India the term is popularly applied chiefly to the southwest monsoon and, by extension, to the rains that it brings. (Ref. 20)

MONSOON FOREST — Partially or wholly deciduous forest in a tropical region where rainy seasons alternate with long dry seasons, the trees being more-or-less leafless during the dry season. Monsoon forests are rich in woody vinelike plants, but the trees are not as large as in rainforests. (Ref. 20)

MOSAIC — An assemblage of overlapping aerial photographs whose edges have been matched to form a continuous photographic representation of a portion of the earth's surface. (Ref. 3)

MUSKEG — Moss-covered countryside, or continuous boggy ground, e.g., moss bogs of the Canadian forest. (Ref. 30)

NEEDLELEAF — Generally, one of the botanical group of trees that have narrow or needle-shaped leaves, i.e., pine, cedars, hemlocks; often referred to as softwoods. (Ref. 30)

OBLIQUE PHOTOGRAPH — A photograph taken with the camera axis directed between the horizontal and vertical. (Ref. 3)

OVERLAP — The amount by which one photograph includes the same area covered by another, customarily expressed as a percentage. Overlap between aerial photographs in the same flight is called "forward overlap;" overlap between photographs in adjacent parallel flights is called "lateral overlap." (Ref. 3)

PARALLAX — The apparent displacement of the position of a body with respect to a reference point or system, caused by a shift in the point of observation. (Ref. 3)

PEAT — An acid, dark-colored, soft, usually coarsely fibrous, unconsolidated soil with a 96 to 99 percent content of partly decomposed, somewhat carbonated plant material accumulated under conditions of excessive moisture. (Ref. 20)

PEAT BOG — An area of soft, wet, spongy ground, consisting chiefly of decayed or decaying moss and other vegetable matter, where peat is formed. (Ref. 20)

PHOTOGRAPHIC INTERPRETATION (PHOTO INTERPRETATION) — The act of examining photographic images for the purpose of identifying objects and judging their significance. (Ref. 3)

PHOTOGRAPHIC TONE — Each distinguishable shade variation from black to white. (Ref. 3)

PHREATOPHYTE — A plant that derives its water by roots that penetrate to the water table. (Generally applied to plants in dry regions, such as mesquite.) (Ref. 23)

PLAYA — The flat, or nearly flat, low part of an enclosed basin or temporary lake without an outlet. Also known as a "dry lake." (Ref. 23)

POLAR REGIONS — Those parts of the surface of the earth that have an average temperature of the warmest month of less than 32^{o}F. (Ref. 12)

PSEUDOSCOPIC STEREO — A three-dimensional impression of relief which is the reverse of that actually existing. If the two photographs are interchanged so that the left-hand photograph becomes the right, then the stereoscopic model will fuse to produce a three-dimensional image, the reverse of that obtained in the original grouping. The stereoscopic image resulting from the interchange of the two prints gives a pseudo-relief effect in which the landscape has been, as it were, turned inside out. Such points as appeared near the eyes in the correct placement of the photographs now appear far away. This is also called inverted stereo. (Ref. 3)

PUNA — Vegetation of the high, intermountain plateau (about 12,000-16,000 feet) in the Peruvian and Bolivian Andes, consisting of a sparse cover of coarse grass and shrubs. (Also used to designate the plateau itself.) (Ref. 23)

QUAKING BOG	1. A peat deposit so wet and unconsolidated that the surface oscillates with the impact of a person walking on it. 2. A late vegetational stage in the filling of a lake or pond by encroaching, floating mats of plants, and plant debris. (Ref. 5)
RAIN FOREST	A world formation type found in equatorial regions of high rainfall without a dry period; a tall, evergreen forest type. (Ref. 10)
REMOTE SENSING	A method for determining the characteristics of an object, organism or community from afar. (Ref. 30)
REPRESENTATION FRACTION (R.F.)	The relation between map or photo distance and ground distance, expressed as a fraction (1/25,000) or often as a ratio (1:25,000 or 1 inch on map = 25,000 inches on the ground). Also called "scale." (Ref. 3)
RESOLUTION	The ability of the entire photographic system, including lens, exposure, processing and other factors, to render a sharply defined image. It is expressed in terms of lines per millimetre perceptible. (Ref. 3)
RUN	The line followed by a photographic aircraft in making a photo strip. (Ref. 3)
SALT MARSH	Flat, poorly drained coastal swamps that are flooded by most high tides. (Ref. 14)
SAVANNA	Grassland with scattered, widely spaced trees. (Savannas are very extensive in the tropics, occupying a position between the tropical rainforests and subtropical deserts, but as defined here they are not limited to tropical regions. (Ref. 23)
SCLEROPHYLL	Having a hard, drought-resistant, evergreen leaf, such as the live oak and Eucalyptus. (Ref. 23)
SCRUB	Vegetation dominated by shrubs, especially in semiarid regions. (Ref. 23)
SEDGE	Any of a family of tufted grasslike marsh plants differing from the related grasses in that they have no joints in the stems. (Ref. 9)

SHIFTING CULTIVATION	The practice, common among primitive peoples in tropical highlands, of clearing a few acres of forest and planting a subsistence crop for several seasons, and then abandoning it to revert to forest. Also called milpa, rai, and ladang. (Ref. 23)
SHRUB	A perennial plant having persistent woody stems branching near the base, not rigid and with low stature. (Ref. 23)
SPINIFEX	A very coarse, xerophytic grass (Triodia) growing in sparse clumps over much of the interior of Australia. (Ref. 23)
STAND	An aggregation of plants, ordinarily trees, standing in a definite limited area. (Ref. 30)
STEPPE	The Russian word for an extensive grassy plain. (In geographical usage if refers to a semiarid, treeless region.) (Ref. 23)
STEREOGRAM	A set of photographs or drawings correctly oriented and mounted for stereoscopic viewing. (Ref. 3)
STEREOSCOPE	A binocular optical instrument for assisting the observer to view two properly oriented photographs or diagrams, to obtain the mental impression of a three-dimensional model. (Ref. 3)
STEREOSCOPIC IMAGE	The mental impression of a three-dimensional object which results from stereoscopic vision. (Ref. 3)
STEREOSCOPIC PAIR	Two photographs with sufficient overlap and consequent duplication of detail to make possible stereoscopic examination of an object or an area common to both. (Ref. 3)
STEREOSCOPIC VISION	That application of binocular vision which enables the observer to view an object simultaneously from two different points of view (as two photographs taken from different camera stations) to obtain the mental impression of a three-dimensional model. (Ref. 3)
STRIP	Any number of photos taken along a photo flight line, usually at an approximately constant altitude. (Ref. 3)
SWAMP	An area of continuously saturated ground, supporting vegetation of predominantly woody plants whose root systems are adapted to prolonged submergence. (Sometimes used as synonymous with "marsh," but here differentiated on the basis of its woody vegetation.) (Ref. 23)

TAIGA	Flat, marshy subarctic forest; usually of spruce, firs or pine trees; the area between the tundra and between tundra and the steppe (in Russia) and deciduous forest or grassland in North America. (Ref. 30)
TEXTURE	In a photo image, the frequency of change and arrangement of tones. Some descriptive adjectives for textures are fine, medium, or coarse; and strippled or mottled. (Ref. 3)
TOPOGRAPHY	The physical features, both natural and manmade, of the surface of the earth. In terrain analysis the following categories of topographical features are considered: relief, drainage, surface materials, vegetation, special physical phenomena, and manmade (cultural) features. (Ref. 13)
TRANSECT	A line through a community on which are indicated the important characteristics of the individuals observed. (Ref. 30)
TREE	A woody, perennial plant with single main stem, more than 2 meters tall.
TREE LINE	The upper limit of tree growth in mountain regions, or the northern limit of erect trees in the Arctic. (Actually a transition zone rather than a sharp line.) Also called "timberline." (Ref. 23)
TROPICAL CLIMATE	The climate observed in the hot-wet tropics or torrid zone of the earth. The outstanding characteristics of tropical regions are hot, but not very hot, temperatures, frequent rain, and high humidity. (Ref. 9)
TUNDRA	Vegetation of the north polar region, consisting of dwarf shrubs, herbs, and lichens. (Ref. 23)
UNDERSTORY	Vegetation zone lying between the forest canopy (overstory) layer and the vegetation covering the ground (ground cover). (Ref. 30)
VEGETATION	Plants in general, or the total assemblage of plants, and their gross appearance as determined by the largest and most common. (Ref. 30)
WOODLAND	A stand of low trees with sufficiently open or widely spaced crowns to permit substantial light to reach the ground layer. (Ref. 23)
XEROPHYTE	A plant that is adapted to a dry habitat. (Ref. 23)

APPENDIX F.

CONVERSIONS AND EQUIVALENTS

LENGTH *

English

1 inch	=	1,000 mils
1 hand	=	4 inches (in.)
1 Gunter's or surveyor's link	=	0.66 feet = 7.92 inches
1 foot	=	12 inches
1 yard	=	3 feet (ft.)
1 fathom	=	6 feet
1 rod, pole, or perch	=	5.5 yards (yd.)
1 chain	=	4 rods = 22 yards = 100 links
1 furlong	=	10 chains = 220 yards
1 mile	=	8 furlongs = 1,760 yards
	=	5,280 feet
1 international nautical mile	=	1.150,779,45 miles
	=	6,076.115,49 feet

Metric

1 millimicron	=	10 ångströms (Å)
1 micron	=	1,000 millimicrons (mμ.)
1 millimetre	=	1,000 microns (μ.)
1 centimetre	=	10 millimetres (mm.)
1 decimetre	=	10 centimetres (cm.)
1 metre	=	10 decimetres (dm.)
1 decametre	=	10 metres (m.)
1 hectometre	=	10 decametres (dam.)
1 kilometre	=	10 hectometres (hm.)
	=	1,000 metres
1 myriametre (mam.)	=	10 kilometres (km.)

Conversions

Basic relationship:

1 inch	=	2.54 centimetres (exactly)
1 international nautical mile	=	1.852 kilometres (exactly)

1 inch	=	2.54 centimetres (exactly)
1 centimetre	=	0.393,700,8 inches
1 hand	=	10.16 centimetres (exactly)
1 link	=	20.116,8 centimetres (exactly)
1 centimetre	=	0.049,709,70 links
1 foot	=	30.48 centimetres (exactly)
1 metre	=	3.280,840 feet
1 yard	=	0.914,4 metres (exactly)
1 metre	=	1.093,613 yards
1 fathom	=	1.828,8 metres (exactly)
1 metre	=	0.546,806,6 fathoms
1 rod, pole, or perch	=	5.029,2 metres (exactly)
1 metre	=	0.198,838,8 rods, poles, or perches
1 chain	=	20.116,8 metres (exactly)
1 metre	=	0.049,709,70 chains
1 furlong	=	201.168 metres (exactly)
1 metre	=	0.004,970,970 furlongs
1 mile	=	1.609,344 kilometres (exactly)
1 kilometre	=	0.621,371,2 miles
1 international nautical mile	=	1.852 kilometres (exactly)
1 kilometre	=	0.539,956,8 nautical miles

*Rennie, P. J., "Measure for Measure," Canada Dept. of Forestry and Rural Development, Publication No. 1195, 1967.

AREA

English

1 square link	= 0.435,6 square feet
	= 62.726,4 square inches
1 square foot	= 144 square inches
1 square yard	= 9 square feet
	= 1,296 square inches
1 mil-acre	= 4.84 square yards
	= 100 square links
1 square rod, pole, or perch	= 30.25 square yards
	= 625 square links
1 square chain	= 16 square rods
	= 484 square yards
	= 10,000 square links
1 rood	= 40 square rods
1 acre	= 4 roods = 10 square chains
	= 160 square rods
1 acre	= 4,840 square yards
	= 43,560 square feet
	= 100,000 square links
1 square mile	= 640 acres
	= 3,097,600 square yards
	= 27,878,400 square feet

Metric

1 square centimetre	= 100 square millimetres
1 square metre (centiare)	= 10,000 square centimetres
1 square decametre (are)	= 100 square metres
1 hectare	= 100 ares (a.)
	= 10,000 square metres
1 square kilometre	= 100 hectares (ha.)
	= 1,000,000 square metres

Conversions

Basic relationship:

1 inch	= 2.54 centimetres (exactly)
1 square inch	= 6.451,6 square centimetres (exactly)
1 square centimetre	= 0.155,000,3 square inches
1 square link	= 404.685,642,24 square centimetres (exactly)
1 square centimetre	= 0.002,471,054 square links
1 square foot	= 0.092,903,04 square metres (exactly)
1 square metre	= 10.763,910 square feet
1 square yard	= 0.836,127,36 square metres (exactly)
1 square metre	= 1.195,990 square yards
1 mil-acre	= 4.046,856,422,4 square metres (exactly)
1 square metre	= 0.247,105,4 mil-acres
1 square rod, pole, or perch	= 25.292,852,64 square metres (exactly)
1 square metre	= 0.039,536,86 square rods
1 square chain	= 404.685,642,24 square metres (exactly)
1 square metre	= 0.002,471,054 square chains
1 acre	= 0.404,685,642,24 hectares (exactly).
1 hectare	= 2.471,054 acres
1 square mile	= 2.589,988,110,336 square kilometres (exactly)
1 square kilometre	= 0.386,102,2 square miles

Map Ratio scale*	Feet per inch	Inches per 1,000 feet	Inches per mile	Miles per inch	Meters per inch	Acres per square inch	Square inches per acre	Square miles per square inch
1: 500	41.667	24.00	126.72	0.008	12.700	0.0399	25.091	0.00006
1: 600	50.00	20.00	105.60	.009	15.240	.0574	17.424	.00009
1: 1,000	83.333	12.00	63.36	.016	25.400	.1594	6.273	.00025
1: 1,200	100.00	10.00	52.80	.019	30.480	.2296	4.356	.00036
1: 1,500	125.00	8.00	42.24	.024	38.100	.3587	2.788	.00056
1: 2,000	166.667	6.00	31.68	.032	50.800	.6377	1.568	.00100
1: 2,400	200.00	5.00	26.40	.038	60.960	.9183	1.089	.0014
1: 2,500	208.333	4.80	25.344	.039	63.500	.9964	1.004	.0016
1: 3,000	250.00	4.00	21.12	.047	76.200	1.4348	.697	.0022
1: 3,600	300.00	3.333	17.60	.057	91.440	2.0661	.484	.0032
1: 4,000	333.333	3.00	15.84	.063	101.600	2.5508	.392	.0040
1: 4,800	400.00	2.50	13.20	.076	121.920	3.6731	.272	.0057
1: 5,000	416.667	2.40	12.672	.079	127.000	3.9856	.251	.0062
1: 6,000	500.00	2.00	10.56	.095	152.400	5.7392	.174	.0090
1: 7,000	583.333	1.714	9.051	.110	177.800	7.8117	.128	.0122
1: 7,200	600.00	1.667	8.80	.114	182.880	8.2645	.121	.0129
1: 7,920	660.00	1.515	8.00	.125	201.168	10.00	.100	.0156
1: 8,000	666.667	1.500	7.92	.126	203.200	10.203	.098	.0159
1: 8,400	700.00	1.429	7.543	.133	213.360	11.249	.089	.0176
1: 9,000	750.00	1.333	7.041	.142	228.600	12.913	.077	.0202
1: 9,600	800.00	1.250	6.60	.152	243.840	14.692	.068	.0230
1: 10,000	833.333	1.200	6.336	.158	254.000	15.942	.063	.0249
1: 10,800	900.00	1.111	5.867	.170	274.321	18.595	.054	.0291
1: 12,000	1,000.00	1.0	5.280	.189	304.801	22.957	.044	.0359
1: 13,200	1,100.00	.909	4.800	.208	335.281	27.778	.036	.0434
1: 14,400	1,200.00	.833	4.400	.227	365.761	33.058	.030	.0517
1: 15,000	1,250.00	.80	4.224	.237	381.001	35.870	.028	.0560
1: 15,600	1,300.00	.769	4.062	.246	396.241	38.797	.026	.0606
1: 15,840	1,320.00	.758	4.00	.250	402.337	40.000	.025	.0625
1: 16,000	1,333.333	.750	3.96	.253	406.400	40.812	.024	.0638
1: 16,800	1,400.00	.714	3.771	.265	426.721	44.995	.022	.0703
1: 18,000	1,500.00	.667	3.52	.284	457.201	51.653	.019	.0807
1: 19,200	1,600.00	.625	3.30	.303	487.681	58.770	.017	.0918
1: 20,000	1,666.667	.60	3.168	.316	508.002	63.769	.016	.0996
1: 20,400	1,700.00	.588	3.106	.322	518.161	66.345	.015	.1037
1: 21,120	1,760.00	.568	3.00	.333	536.449	71.111	.014	.1111
1: 21,600	1,800.00	.556	2.933	.341	548.641	74.380	.013	.1162
1: 22,800	1,900.00	.526	2.779	.360	579.121	82.874	.012	.1295
1: 24,000	2,000.00	.50	2.640	.379	609.601	91.827	.011	.1435
1: 25,000	2,083.333	.480	2.534	.395	635.001	99.639	.010	.1557
1: 31,680	2,640.00	.379	2.000	.500	804.674	160.000	.006	.2500
1: 48,000	4,000.00	.250	1.320	.758	1,219.202	367.309	.003	.5739
1: 62,500	5,208.333	.192	1.014	.986	1,587.503	622.744	.0016	.9730
1: 63,360	5,280.00	.189	1.000	1.000	1,609.347	640.00	.0016	1.0000
1: 96,000	8,000.00	.125	.660	1.515	2,438.405	1,469.24	.0007	2.2957
1: 125,000	10,416.667	.096	.507	1.973	3,175.006	2,490.98	.0004	3.8922
1: 126,720	10,560.00	.095	.500	2.00	3,218.694	2,560.00	.0004	4.00
1: 250,000	20,833.333	.048	.253	3.946	6,350.012	9,963.907	.0001	15.5686
1: 253,440	21,120.00	.047	.250	4.00	6,437.389	10,244.202	.0001	16.00
1: 500,000	41,666.667	.024	.127	7.891	12,700.025	39,855.627	.000025	62.2744
1: 1,000,000	83,333.333	.012	.063	15.783	25,400.050	159,422.507	.0000062	249.0977

*Soil Conservation Service, Aerial-Photo Interpretation in Classifying and Mapping Soils, USDA Handbook 294, 1966

APPENDIX G

EQUIPMENT LIST

Stereoscope, folding pocket type
Crown micrometer wedge
Dot type scale
Crown density scale
Masking tape
Mylar, roll 4 ft. wide
Parallax wedge
Parallax bar
Magnification tube
Stapler
Wax base red pencil
Prisma color pencil
Felt tip pen
Ink solvent
Writing pads
Erasers
Pencils
Green drawing paper 8-1/2" by 11" (probability by 90 divisions)
Engineer's scale
Drop compass set
Needles for point pricking
4' x 8' soft fiber board
4' x 8' sheet of plywood
Saw horses
India ink
White paper
5 place logarithm table
Transparent template w/scribed circles approximating 0.08 hectare
(1/5 acre) at various photographic scales
Light table
Reflecting projector
Zoom transfer scope
Pantograph
Large copy camera
Electronic calculator
Paper cutter
Vertical sketchmaster